

JOHNSON GRANT

IN-61
7304

P-15

SPACECRAFT SOFTWARE TRAINING NEEDS ASSESSMENT RESEARCH APPENDICES

N91-20787

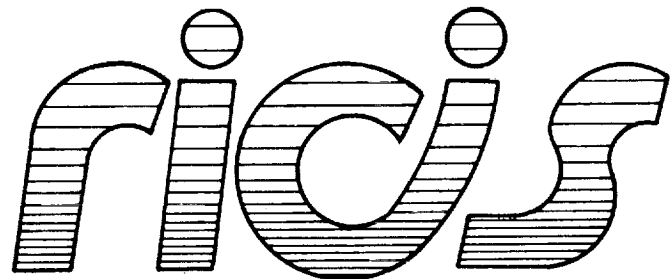
Unclas
63/61 0007304

**Shirley Ratcliff
Katharine Golas
Southwest Research Institute**

April 27, 1990

Cooperative Agreement NCC 9-16
Research Activity No. ET.16

NASA Johnson Space Center
Engineering Directorate
Flight Systems Division



*Research Institute for Computing and Information Systems
University of Houston - Clear Lake*

(NASA-CR-188104) SPACECRAFT SOFTWARE
TRAINING NEEDS ASSESSMENT RESEARCH,
APPENDICES (Houston Univ.) 75 p CSCL 09B

T · E · C · H · N · I · C · A · L R · E · P · O · R · T

The RICIS Concept

The University of Houston-Clear Lake established the Research Institute for Computing and Information systems in 1986 to encourage NASA Johnson Space Center and local industry to actively support research in the computing and information sciences. As part of this endeavor, UH-Clear Lake proposed a partnership with JSC to jointly define and manage an integrated program of research in advanced data processing technology needed for JSC's main missions, including administrative, engineering and science responsibilities. JSC agreed and entered into a three-year cooperative agreement with UH-Clear Lake beginning in May, 1986, to jointly plan and execute such research through RICIS. Additionally, under Cooperative Agreement NCC 9-16, computing and educational facilities are shared by the two institutions to conduct the research.

The mission of RICIS is to conduct, coordinate and disseminate research on computing and information systems among researchers, sponsors and users from UH-Clear Lake, NASA/JSC, and other research organizations. Within UH-Clear Lake, the mission is being implemented through interdisciplinary involvement of faculty and students from each of the four schools: Business, Education, Human Sciences and Humanities, and Natural and Applied Sciences.

Other research organizations are involved via the "gateway" concept. UH-Clear Lake establishes relationships with other universities and research organizations, having common research interests, to provide additional sources of expertise to conduct needed research.

A major role of RICIS is to find the best match of sponsors, researchers and research objectives to advance knowledge in the computing and information sciences. Working jointly with NASA/JSC, RICIS advises on research needs, recommends principals for conducting the research, provides technical and administrative support to coordinate the research, and integrates technical results into the cooperative goals of UH-Clear Lake and NASA/JSC.

***SPACECRAFT SOFTWARE TRAINING
NEEDS ASSESSMENT RESEARCH
APPENDICES***

Preface

This research was conducted under the auspices of the Research Institute for Computing and Information Systems by Shirley Ratcliff and Katherine Golas of Southwest Research Institute. Dr. Glenn Freedman, Director of SEPEC, served as RICIS research representative.

Funding has been provided by Flight Data Systems Division, Engineering Directorate, NASA/JSC through Cooperative Agreement NCC 9-16 between NASA Johnson Space Center and the University of Houston-Clear Lake. The NASA technical monitor for this activity was Robert N. Hinson, of the Software Development Section, Flight Data Systems Division, Engineering Directorate, NASA/JSC.

The views and conclusions contained in this report are those of the author and should not be interpreted as representative of the official policies, either express or implied, of NASA or the United States Government.

Southwest Research Institute
6220 Culebra Road
San Antonio, Texas 78228

Project No. 05-3065

**SPACECRAFT SOFTWARE TRAINING
NEEDS ASSESSMENT RESEARCH**

APPENDICES

Prepared for:

NASA/Johnson Space Center

Prepared by:

Shirley Ratcliff
Katharine Golas, Ph.D.

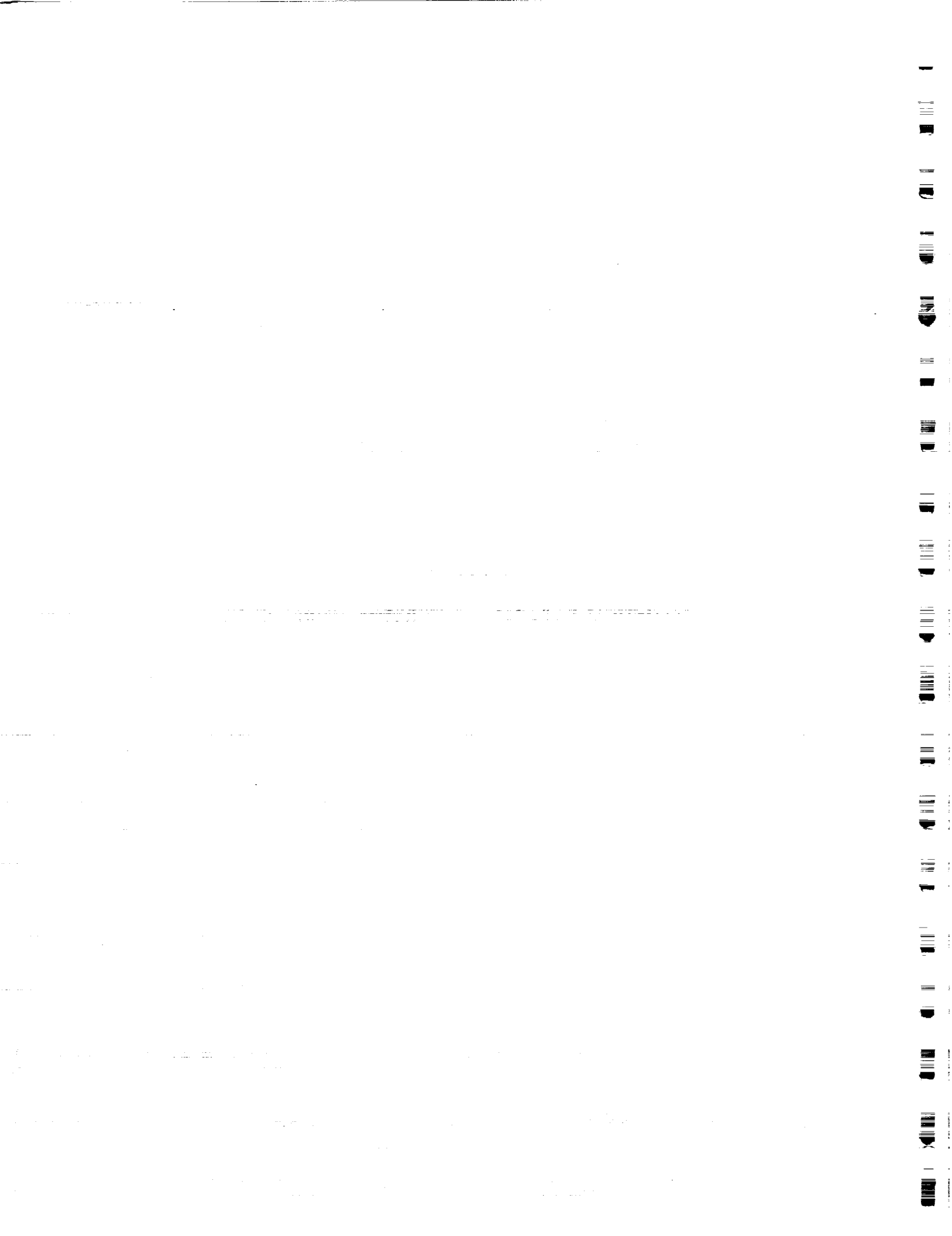
April 27, 1990

LIST OF APPENDICES

Appendix A	Statistical Data from Task Rating Worksheets
Appendix B	SSD References
Appendix C	Survey Forms
Appendix D	Fourth Generation Language, a Powerful, Long-Term Solution to Maintenance Cost
Appendix E	Task List
Appendix F	Methodology
Appendix G	SwRI's Instructional Systems Development Model
Appendix H	Relevant Research
Appendix I	References

APPENDIX A

STATISTICAL DATA FROM TASK RATING WORKSHEETS



STATISTICAL ANALYSIS OF NASA/JSC/SSD TASK RATINGS

DATA COLLECTION

Fourteen questionnaires were collected from individuals employed at NASA. Thirty different jobs or tasks were defined in which individuals rated their perceptions of these jobs according to five different response variables. The ratings from these 14 questionnaires were coded into a data base system so that statistical analyses could then be performed. Table 1 lists the thirty jobs/tasks with their appropriate coding values. Table 2 tabulates data on the five response variables used during the interview and questioning of the NASA employees. These five response variables are (1) task frequency, (2) percent of time on task, (3) task importance, (4) learning difficulty, and (5) personnel. Codings used to transcribe these responses into the data base are also included in Table 2.

Not all individuals interviewed provided answers to every job/task and every response variable. Therefore, the data gathered in this study contains some jobs/tasks with relatively few responses. These jobs/tasks cannot be used in any formal statistical procedure since their sample size is too small. In general, jobs which contained fewer than 10 replies (<70 percent of the sample) were not included in formal statistical summaries. These are job/task numbers 5, 9, 12, 13, 18, 23, 24, 25, 26, 27, 28, and 29.

Pairwise Correlations

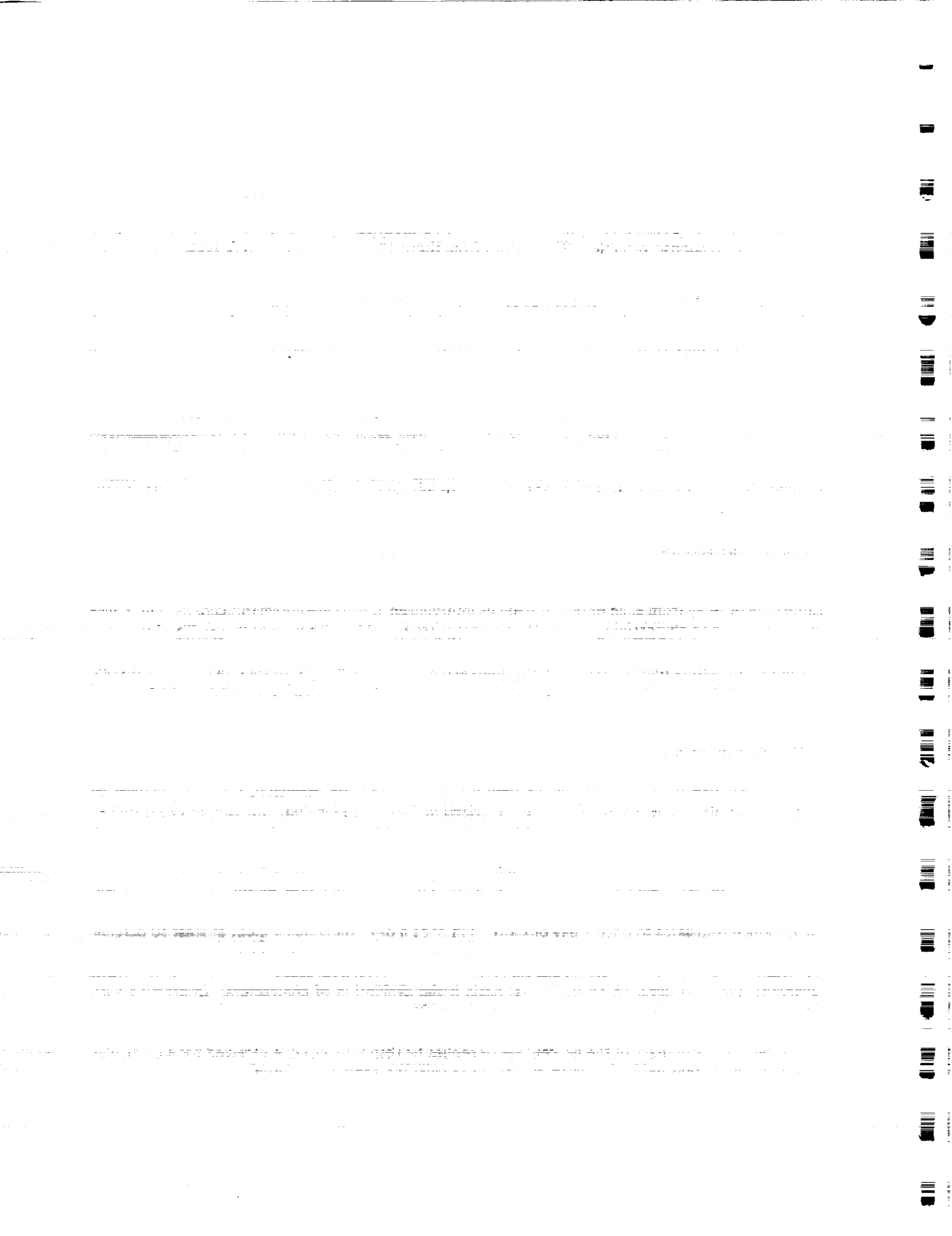
To determine if any of the five response variables were similar or perceived as reflecting the same type of reply from each of the individuals interviewed, a pairwise correlation coefficient, r , was calculated among all possible pairs of the five response variables. These results are listed in Table 3. It can be seen that there is no predominant linear correlation among any two of the response variables, indicating that the response variables are indeed measuring different factors or concepts. As can be seen from Table 3, the highest correlation exists between task frequency and percent of time on task (-0.2947).

Descriptive Statistics

As a synopsis of the data collected, descriptive statistics were calculated for each job/task by response variable. These statistics are summarized in Table 4 and include the sample size (number of responses), the average response rating, and the standard deviation of the response rating. A frequency table of the responses was also generated and appears in Table 5.

Of the job/tasks which contained at least ten replies, the job/task performed the most frequently was 8, interact with other branch members. This response variable had an average reply of 1.6 which translates to once a day or more than once a day. Individuals spent at least 30 percent of their time interfacing with contractors (average = 3.57), which they also claim is very important (average = 4.36). Analyzing test results is the hardest task to learn (average = 3.54) and the job which everyone agrees is done on an individual basis is the evaluation of contractors. Interacting with branch members utilizes a team effort (average = 1.08).

Table 6 is a summary of the percentage of replies by response variable received for a particular job/task. Note that only jobs which contained at least ten replies are listed.



**TABLE 6. Percentage of Replies for Each Response
Variable by Job/Task**

<u>Job/Task</u>	<u>Conclusion</u>		
1: Review SW Requirements	Task Frequency	57%	Once a week to once a month
		29%	Once a day
		14%	More than once a day
	% Time on Task	50%	0 - 10%
		21%	10 - 30%
		29%	30 - 50%
	Task Importance	50%	Very important
		43%	Important
		7%	Somewhat important
	Learning Difficulty	69%	Hard to learn
		23%	Easy to learn
		8%	Very hard to learn
2: Research SW Requirements	Personnel	71%	Individual
		29%	Teamwork
	Task Frequency	50%	Once a week to once a month
		25%	Once a day
		17%	More than once a day
		8%	Twice a year
	% Time on Task	50%	0 - 10%
		25%	30 - 50%
		17%	10 - 30%
		8%	70 - 100%
	Task Importance	50%	Very important
		42%	Important
		8%	Somewhat important
3: Interface with Contractor	Learning Difficulty	91%	Hard to learn
		9%	Easy to learn
	Personnel	75%	Individual
		25%	Teamwork
	Task Frequency	50%	More than once a day
		29%	Once a day
		21%	Once a week to once a month
	% Time on Task	57%	10 - 30%
		21%	50 - 70%
		7%	0 - 10%
		7%	30 - 50%
		7%	70 - 100%

	Task Importance	86%	Very important
		14%	Important
	Learning Difficulty	64%	Easy to learn
		22%	Hard to learn
		7%	Very easy to learn
		7%	Very hard to learn
	Personnel	54%	Individual
		46%	Teamwork
4: Attend Board Meetings	Task Frequency	72%	Once a day
		21%	Once a week to once a month
		7%	More than once a day
	% Time on Task	46%	10 - 30%
		31%	0 - 10%
		15%	30 - 50%
		8%	50 - 70%
	Task Importance	64%	Very important
		36%	Important
	Learning Difficulty	50%	Hard to learn
		22%	Easy to learn
		14%	Very easy to learn
		14%	Very hard to learn
	Personnel	71%	Teamwork
		29%	Individual
6: Attend Additional Board Meetings	Task Frequency	58%	Once a week to once a month
		17%	Twice a year
		8%	More than once a day
		8%	Once a day
		8%	Once a year to less than once a year
	% Time on Task	58%	0 - 10%
		17%	10 - 30%
		8%	30 - 50%
		8%	50 - 70%
		8%	70 - 100%
	Task Importance	58%	Very important
		25%	Important
		17%	Somewhat important
	Learning Difficulty	50%	Hard to learn
		33%	Easy to learn
		17%	Very hard to learn
	Personnel	50%	Teamwork
		50%	Individual

7: Prepare FSW Management Forms	Task Frequency	46%	Once a day
		46%	Once a week to once a month
		8%	Twice a year
	% Time on Task	54%	10 - 30%
		30%	30 - 50%
		8%	0 - 10%
		8%	50 - 70%
	Task Importance	69%	Very important
		15%	Important
		8%	Somewhat important
		8%	Not important or not necessary
8: Interact with Branch Members	Learning Difficulty	69%	Hard to learn
		23%	Very hard to learn
		8%	Easy to learn
	Personnel	77%	Individual
		23%	Teamwork
	Task Frequency	57%	Once a day
		43%	More than once a day
	% Time on Task	50%	10 - 30%
		29%	0 - 10%
		21%	30 - 50%
10: Support SASCB	Task Importance	57%	Very important
		43%	Important
	Learning Difficulty	64%	Easy to learn
		36%	Very easy to learn
		8%	Easy to learn
	Personnel	92%	Teamwork
		8%	Individual
	Task Frequency	92%	Once a week to once a month
		8%	Twice a year
	% Time on Task	62%	10 - 30%
		38%	0 - 10%
	Task Importance	62%	Very important
		15%	Important
		15%	Somewhat important
		8%	Not important or not necessary

	Learning Difficulty	38%	Easy to learn
		38%	Hard to learn
		23%	Very hard to learn
	Personnel	69%	Individual
		31%	Teamwork
11: Participate in Working Groups	Task Frequency	80%	Once a week to once a month
		10%	Twice a year
		10%	Once a year to less than once a year
	% Time on Task	70%	0 - 10%
		20%	10 - 30%
		10%	50 - 70%
	Task Importance	33%	Very important
		33%	Important
		22%	Not important or not necessary
		11%	Somewhat important
	Learning Difficulty	56%	Easy to learn
		22%	Hard to learn
		11%	Very hard to learn
		11%	Very easy to learn
	Personnel	78%	Teamwork
		22%	Individual
14: Review Test Plan/Spec	Task Frequency	70%	Once a week to once a month
		30%	Once a day
	% Time on Task	50%	0 - 10%
		40%	10 - 30%
		10%	30 - 50%
	Task Importance	60%	Very important
		30%	Important
		10%	Not important or not necessary
	Learning Difficulty	50%	Hard to learn
		30%	Easy to learn
		20%	Very hard to learn
	Personnel	60%	Teamwork
		40%	Individual
15: Review Verify Test Procedures	Task Frequency	83%	Once a week to once a month
		17%	Twice a year
	% Time on Task	58%	10 - 30%
		42%	0 - 10%

	Task Importance	58%	Very important
		33%	Important
		8%	Somewhat important
	Learning Difficulty	83%	Hard to learn
		8%	Easy to learn
		8%	Very hard to learn
	Personnel	67%	Individual
		33%	Teamwork
16: Review Verify Test Cases	Task Frequency	83%	Once a week to once a month
		17%	Twice a year
	% Time on Task	58%	10 - 30%
		25%	0 - 10%
		17%	30 - 50%
	Task Importance	75%	Very important
		17%	Important
		8%	Somewhat important
	Learning Difficulty	58%	Hard to learn
		33%	Very hard to learn
		8%	Easy to learn
	Personnel	50%	Individual
		50%	Teamwork
17: Analyze Test Results	Task Frequency	90%	Once a week to once a month
		10%	Twice a year
	% Time on Task	45%	0 - 10%
		45%	10 - 30%
		10%	30 - 50%
	Task Importance	55%	Very important
		27%	Somewhat important
		18%	Important
	Learning Difficulty	55%	Very hard to learn
		45%	Hard to learn
	Personnel	55%	Teamwork
		45%	Individual
19: Maintain Current Professional Knowledge	Task Frequency	31%	Once a year to less than once a year
		31%	Twice a year
		23%	Once a day
		15%	Once a week to once a month

	% Time on Task	54%	0 - 10%
		46%	10 - 30%
	Task Importance	62%	Very important
		31%	Important
		8%	Somewhat important
	Learning Difficulty	50%	Hard to learn
		25%	Very hard to learn
		17%	Easy to learn
		8%	Very easy to learn
	Personnel	92%	Individual
		8%	Teamwork
20: Monitor Processes	Task Frequency	64%	Once a week to once a month
		18%	More than once a day
		10%	Once a day
		10%	Twice a year
	% Time on Task	45%	0 - 10%
		27%	10 - 30%
		9%	30 - 50%
		9%	50 - 70%
		9%	70 - 100%
	Task Importance	55%	Very important
		27%	Not important or not necessary
		9%	Somewhat important
		9%	Important
	Learning Difficulty	50%	Easy to learn
		40%	Hard to learn
		10%	Very easy to learn
	Personnel	50%	Individual
		50%	Teamwork
21: Attend CIP and CI Meetings	Task Frequency	79%	Twice a year
		21%	Once a year to less than a year
	% Time on Task	72%	0 - 10%
		21%	10 - 30%
		7%	30 - 50%
	Task Importance	43%	Very important
		29%	Important
		14%	Somewhat important
		14%	Not important or not necessary

	Learning Difficulty	54%	Easy to learn
		31%	Hard to learn
		15%	Very easy to learn
	Personnel	62%	Teamwork
		38%	Individual
22: Evaluate Contractors	Task Frequency	64%	Once a week to once a month
		36%	Twice a year
	% Time on Task	57%	0 - 10%
		29%	10 - 30%
		14%	30 - 50%
	Task Importance	57%	Very important
		29%	Important
		14%	Somewhat important
	Learning Difficulty	77%	Hard to learn
		15%	Very hard to learn
		8%	Easy to learn
	Personnel	100%	Individual
30: Other Support Tasks	Task Frequency	45%	Once a week to once a month
		36%	Once a day
		9%	More than once a day
	% Time on Task	45%	10 - 30%
		27%	0 - 10%
		18%	30 - 50%
		9%	50 - 70%
	Task Importance	64%	Very important
		27%	Somewhat important
		9%	Important
	Learning Difficulty	80%	Hard to learn
		10%	Very hard to learn
		10%	Easy to learn
	Personnel	70%	Individual
		30%	Teamwork

APPENDIX B

REFERENCES

GENERAL REFERENCES

- AutoLib Product Overview. Barrios, July 1989.
- Configuration Control During OBS FSW Implementation. R. De la Fuente, June 1989.
- CR Selection Process for GN & C LVL7 Testing. T. Talbert, November 1988.
- Data Processing System (Hardware and Systems Software). NASA, April 1986.
- Data Processing System Redundancy Management Architecture. Author and date unknown.
- Development of Dynamic & Interactive Spatial Representation. Dr. Jim Schroeder, SwRI, 1988.
- DOD Trusted Computer System Evaluation Criteria. Paul Breaux, SwRI, August 1983.
- Electronic Library Project. Ken Jenks, October 1987.
- Electronic Based Software Requirements Problem Definition and Status. S. Kolkhorst, March 1988.
- Flight Software Branch Reorganization Charts.
- FR251 Position Description. FSB, date unknown.
- Level 6 Process Overview. Earl Lee, July 1989.
- 01-8C Flight Software Program Notes and Waivers, Addendum 2.
- OBS On Line SW Requirements Demonstration Data Package Contents. Contractor produced, date unknown.
- On Line Management Information Network for the Shuttle Avionics Software Control Board User's Guide and Requirements. IBM, May 1988.
- Overview of the IBM Level 6 Verification Process. J. Haugh, July 1989.
- Program Notes & Waivers (OI-8C). NASA, October 1989.
- Shuttle Avionics Flight Software Integration Testing Report on Tools & Methods. August 1987.
- Spacecraft Software Division Organizational Chart.
- Systems Management/Payload Functions. M. Creech, May 1988.
- System Software Functional Overview. M. Somers. April 1988.
- Test and Operations Procedures and Support Software Reference. NASA, June 1989.

SAMPLE PRESENTATIONS

- BFS Certification, SSD. Author and date unknown.
- BFS Integrated Software Change Control Management System with the Software Management Utility. D. Eldridge, date unknown.
- BUS Reconfiguration Concepts/Effects. M. Queener, July 1988.
- Entry Flight Control Overview. A. Currie, January 1989.
- Downlist Verses Downlink. D. Pipkins, November 1987.
- FEID Modification Overview. M. Briedon, 1989.
- Guidance (Ascent Phase). Pipkins & Perera, November 1989.
- Integrated Software Engineering Education and Training Plan. Glenn Freedman, August 1989.
- Level 6 Process Overview. Earl Lee, July 1989.
- Library Management System Presentation. Barrios Technology, October 1989.
- Mission Control Center Overview. S. Seyl, date unknown.
- Mission Operations Directorate - Operations Division Electronic Library Project. Ken Jenks, October 1989.
- 1-Load Reconfiguration Process Overview of PASS and BFS Processes. D. Eldridge, May 1988.
- PASS Certification. D. Pipkins, February 1988.
- PASS Architecture. J. Newman, January 1988.
- SSIP & ICC Overview. Stephenson/E. Fountain, April 1989.
- Systems Management/Payload Functions. M. Creech, May 1988.
- Tools CRs and DRs Process Overview. D. Eldridge, February 1988.
- Vehicle Utility Functional Capabilities. S. Dean, May 1988.

SAMPLE HANDOUTS/DOCUMENTS

- DR Board Summary & Handout.
- FR2 Weekly Meeting Schedule, week 1-2.
- IBCB Flight Products Listing (Example), Sharyl Butler.
- Pass Status (Example), "Automated" OI Tool (Caperton).
- STS MER Schedule (Example) SSD, Stephenson.

TRAINING REFERENCES

- Ascent Guidance and Flight Control Training Manual. NASA, August 1989
- Bus Reconfiguration CBT. Barrios, November 1989
- DPSD Courses for JSC. June 1989.
- Existing SMAP Courses.
- FR2/SSD/MSD Training. Joe L. Seale. February 1988.
- Guidance, Navigation and Control CBT. Barrios, December 1989.
- MOD/FCOD Training Materials Library Inventory. Newman, June 1989.
- Mod Phase I Program Guide.
- NASA Software Management and Assurance Training Courses.
- Project Management, SMAP.
- Proposed SMAP Courses.
- Quality Assurance, SMAP, E. Fountain.
- Software Acquisition MGMT Course Summary.
- Software Configuration Management. SMAP, E. Fountain.
- Software Verification & Validation. SMAP, E. Fountain.
- SSW Training Class. M. Briedon, December 1988.
- Summary of MOD Phase I Orientation. E. Fountain, April 1988.

APPENDIX C
SURVEY FORMS

INTERVIEW SURVEY INSTRUMENT FOR NASA/JSC/SSD PROGRAM ANALYSTS

Name of Interviewer: _____

Date of Interview: _____

1. BACKGROUND INFORMATION

- a. Name: _____
- b. Job Title/Grade: _____
- c. Phone Number: _____
- d. Number of Years in present job: _____
- e. Previous NASA job positions and length of employment in each: _____

- f. Previous job experience related to current NASA position: _____

- g. Formal educational degree(s): _____
- h. Name of supervisor: _____
- i. Number of personnel you supervise: _____
- j. Personnel you interact with most frequently: _____

2. JOB/TASK ASSIGNMENTS AND WORK SPECIFICATIONS

- a. Please describe your job in general terms. _____

b. Do you have a set schedule? (Day-by day or week-by-week)? If yes, please describe. _____

c. What Boards are you involved with and in what capacity? _____

3. TRAINING SUPPORT

a. How were you trained for the special knowledge and skills necessary for your job? _____

b. What were the strengths and weaknesses of this training? _____

c. Do you currently receive training for new job assignments? If yes, please describe strengths and weaknesses of that training. _____

d. How much time do you spend in training each month? _____

e. How much time could you spend in training each month? _____

f. If you had to hire a new employee to do your job, what qualities would you look for? _____

g. What kinds of things could be provided to help this person understand how to do the job quickly and proficiently? _____

h. Would you like to receive more training in your current job position? If yes, please elaborate. _____

**INTERVIEW SURVEY INSTRUMENT FOR
NASA/JSC/SSD SUPERVISORS**

Name of Interviewer: _____

Date of Interview: _____

1. BACKGROUND INFORMATION

a. Name: _____

b. Job Title/Grade: _____

c. Phone Number: _____

d. Number of years in present job: _____

e. Previous NASA job positions and length of employment in each: _____

f. Previous job experience related to current NASA position: _____

g. Formal educational degree(s): _____

h. Name of supervisor: _____

2. CHARACTERISTICS OF PERSONNEL SUPERVISED

a. Number of personnel you supervise: _____

b. Personnel you interact with most frequently: _____

c. General education of personnel you supervise: _____

d. General skills and abilities of personnel you supervise: _____

e. General attitude of personnel you supervise towards jobs: _____

j. Where and how do personnel currently receive training? _____

k. Does NASA currently provide training? _____

l. Can or do personnel receive training from other sources? _____

m. What do you perceive is the major problem with the software maintenance procedures as they stand today? _____

1. If you perceive that there is a problem, what do you think is the cause? _____

2. How should the system be working? _____

3. What should be happening that is not happening? _____

4. What do you think are the options for solving the problem? _____

n. What is the availability of resources (hardware, software, reference materials) for your staff? _____

3. JOB PERFORMANCE OF PERSONNEL

- a. Is their performance adequate, fair, poor, excellent? _____
- b. What do they do best? _____

- c. If what areas (job tasks) do they need the most improvement? _____

- d. What are the major constraints that seem to limit their performance? _____

- e. Any other problems that keep your staff from performing adequately? _____

- f. What positions (if any) do you have the most trouble keeping adequately staffed? _____

- g. What problems do you think could be eliminated by training? _____

- h. Who do you think needs training the most? _____

- i. What job functions are the most crucial? _____

JOB POSITION

JOB POSITION	TASK FREQUENCY	% OF TIME ON TASK	TASK IMPORTANCE	LEARNING DIFFICULTY	PERSONNEL	TRAINING
	DAILY ONCE A DAY ONCE A WEEK TWICE A MONTH ONCE A YEAR LESS THAN ONE A YEAR	0% 10% 20% 30% 40% 50% 60% 70% 80% 90% 100%	1 2 3 4 5	EASY TO LEARN TO LEARN STANDARD HARD TO LEARN VERY HARD TO LEARN TEAMWORK INDIVIDUAL COURSES ON THE JOB OTHER		
JOB/TASKS						
1 Review SW Requirements						
2 Research SW Requirements						
3 Interface with Contractor						
4 Attend Board Meetings						
5 Chair Boards						
6 Attend Addtl Board Meetings						
7 Prepare PSW Mgmt Form						
8 Interact with Branch Members						
9 Support Pre-SASCB						
10 Support SASCB						
11 Participate in working grps						
12 Produce Program Notes						
13 Develop Scenario						
14 Review Test Plan/Spec						
15 Review Verify Test Procedures						
16 Review Verify Test Cases						
17 Analyze Test Results						
18 Control Documentation						
19 Maintain Current Prof Know						
20 Monitor Processes						
21 Attend CIP and CI Meetings						
22 Evaluate Contractors						
23 Develop Training/Present						
24 Make Tech Presentations						
25 Manage Facility						
26 Support Tasks						
27						
28						
29						
30						

- Software work could be managed without the performance of this task
- Performance of task is not necessary but it would be nice if money and personnel were available
- This task should be performed to manage software work adequately
- Inadequate management of software work if this task is not performed
- Severe consequences will result if this task is not performed

APPENDIX D

FOURTH GENERATION LANGUAGE, A POWERFUL, LONG-TERM SOLUTION TO MAINTENANCE COST

The attached article was written by Mr. Paul Breau, a research analyst at SwRI, and accepted for publication in the Government Computer News. Before coming to SwRI, Mr. Breau was the Chief of Configuration Management (CM) for the Joint Chiefs of Staff (JCS) in Washington, D.C. In this position, Mr. Breau established all configuration management policies and procedures for the JCS. He was instrumental in establishing a near paperless office automation environment in the JCS using available 4th Generation Language tools and networking technology. The current JCS office automation environment allows full coordination of message traffic, publications, and documentation including red-line changes without requiring hard copies, E-mail, the interactive scheduling of conference facilities and meetings, business graphics, spreadsheet services, individual tickler support, bulletin board services, distributed data basing, archival support, interactive financial transaction support, and complete configuration management support including interactive problem reporting, analysis, tracking, and CM Board administrative support.

Fourth Generation Languages, A Powerful, Long-Term Solution to Maintenance Cost

Currently, it is estimated that 40 to 80 percent of information systems costs are directly attributed to maintenance. In addition, results of numerous surveys indicate that 60 to 70 percent of DOD software dollars are spent annually on software maintenance. Everyone can agree that the cost of information system's maintenance can adversely affect what programs are changed and when changes are accomplished. The following is a brief on what is a Fourth-Generation Language (4GL), benefits gained by using 4GLs, and some of the limitations of using 4GLs.

4GLs were designed to meet two specific objectives. First, to assist nonprogrammers in generating software applications without learning more complex conventional high-level programming languages. Second, to assist in increasing the productivity of the normal programming process. They are meant to be languages that are easy to learn and simple to use by nonprogramming individuals. 4GLs are usually tied to specific functions such as graphics languages, Data Base Management Systems (DBMS), and report/application generators. They give the user a somewhat less complex method of setting screen displays and report formats.

The use of 4GLs can reduce the traditionally lengthy software modification cycle. The design of most 4GLs allows users to find the area needing change and with minimal key-strokes make the change in an expeditious manner. Well-designed 4GLs will normally allow 80 percent of routine changes to be made in one hour, whereas, it may take months using conventional methods of programming.

Also, since most applications developed using 4GLs are easy to understand, different people from those who initially programmed the application are able to make changes to existing code within a short period of time and with minimal frustration.

Most 4GLs are designed to prevent ill-structured program constructs which could cause problems after the application is implemented. A good 4GL will walk the user through the sequence of operations in a clear, concise, structured manner and generate English-like source code into transparent object code. The user does not have to worry about learning structured programming constructs to get the job done.

Some 4GLs provide automatic and/or selectable error trapping. It is nearly impossible to identify and provide error trapping on every possible type of error that may occur within a program using conventional program methodology. However, many 4GLs provide automatic error trapping or allow the user to identify specific error conditions and/or provide error messages to be tailored to individual user needs.

Many 4GLs are self-documenting. For example, some 4GLs insert comments into existing source code as the application is being generated. This means that users do not have to take time away from normal duties to document software that is being developed or modified. In addition, the documentation can be used for future modifications to existing applications.

Due to the ease of use of most 4GLs, users are able to make their own enhancements, especially to screen displays and report formats. This will allow the programming staff to use valuable and expensive application development time for more complex applications.

In some cases, end-users are able to generate and maintain entire applications. Some 4GLs are so user-friendly that most end-users, with time and a desire to learn a 4GL, can generate and maintain simple applications. Again, this relieves programming staff for more complex programming tasks.

Many 4GLs are either linked to or are part of a DBMS. The applications are tied to self-generating data dictionaries which allow them to make full use of existing data bases. Data bases are becoming very common in the work place. A well-designed 4GL linked to a DBMS allows users to design and build screen displays and generate reports that can increase the efficiency of most organizations.

Although the use of 4GLs allows users to develop applications faster and provide more cost efficient maintenance, there are some limitations. The following limitations should be considered when purchasing and/or using 4GLs.

For example, some applications are too complex for 4GLs. Even with a high-level programming language interface, some applications should not be attempted using 4GLs. 4GLs are best used with simple, routine applications required for reporting specific information (usually tied to stored data).

Depending on the design of the 4GL, response time may be slow. Because 4GLs are designed to make the job of creating and maintaining applications easier, it carries some overhead. This overhead is additional code that is generated each time an application is developed or modified. This additional code is generated whether it is used by the application or not. This overhead may effect the response time regarding data base queries, graphic presentations, and report generation. Responsiveness should be considered when selecting a 4GL for use in application development.

As related in the previous paragraphs, there is overhead with 4GLs and this may affect the amount of internal and external storage space used by applications. 4GL applications tend to take up approximately one half to twice as much storage space as required for conventional applications. If there is limited storage space, care must be taken when using 4GLs.

Some 4GLs are not general purpose enough to meet most routine application requirements. There exist 4GLs that are designed to meet specific functional requirements such as graphics, report generation, query operations, or application generation only. Based on user requirements, the 4GL selected should be a combination of these functions with a seamless (if possible) interface between complementary functions.

Finally, the use of 4GLs can breed complacency regarding data administration. Some users believe that because some 4GLs provide well-structured application software, there is no need to model or efficiently design data structures that are required for use with the 4GL. Poorly designed data structures could adversely affect the performance of the 4GL. Care must be taken with data administration in order to get the most from a 4GL.

An example regarding the use of 4GLs can be found at the Joint Chiefs of Staff (JCS). Currently, the JCS uses the PACE DBMS on Wang minicomputer systems. On the average, six applications are developed each month that would normally take three months to develop using conventional programming languages. Most of these applications are developed in less than two weeks. The majority of applications deal with user-friendly, form-like screens tied to stand alone data bases. However, with appropriate access authorization, these applications can be used by remote users through the Local Area Network (LAN).

In conclusion, this brief has provided eight reasons how 4GLs can decrease software development and maintenance costs and some limitations to consider when selecting or using a 4GL. This brief should establish that even with some limitations, it is still worth any organization's time and money to look into using 4GLs for many of their routine software application development

APPENDIX E

TASK LIST

ANALYST'S TASKS

Process DR/CR

- Review SW Requirements (CR/DR)
- Research SW Requirements
- Interface with Contractor Personnel (Disposition/Severity)
- Attend Board Meetings (PASS & BFS DR)
- Chair Boards
- Attend Additional Board Meetings
- Prepare FSW Mgmt forms
- Interact with other Branch Members
- Support Pre-SASCB
- Support SASCB
- Participate in working groups and mode teams
- Produce Program Notes on Waiver's Document (each OI & Flight)

Testing

- Develop Scenario
- Review Test Plan/Specification
- Review Verification Test Procedures
- Review Verification Test Cases
- Analyze Test Results

Support Tasks

- Principal Function Managers (IPL, DCP, BSS)
- Certification Manager
- DR Manager
- OI Manager
- Mission Manager
- Backup/Substitute
- Flight Support
- Release Manager
- T&O Manager
- Produce Support Tools Document (once every OI)
- Book Manager

General Tasks

- Control Documentation - Publish of Design Documents
 - CPDS(IBM), PRD(Rockwell)
- Maintain Current Professional Knowledge
- Monitor Processes - Development Plan Review Meetings (Schedule Status & Integration Planning)
- Attend CIP and CI Meetings
- Evaluate Contractors
- Develop Training/Presentations
- Make Technical Presentations to Upper/Mid Management
- Manage Facility

APPENDIX F
METHODOLOGY FOR STUDY

METHODOLOGY FOR STUDY

Analysis Techniques

Two powerful analysis techniques were used in performance of the TNA effort for the Flight Software Branch: needs assessment analysis and subject matter/task analysis.

Needs Assessment Technique

Needs assessment is the systematic effort that SwRI followed to gather opinions and ideas from a variety of sources on performance problems. The needs assessment technique was the primary vehicle SwRI used to acquire information which was crucial for seeking a clear picture of the analysts' opinions and conceptualization of the problems they encounter.

Subject Matter/Task Analysis Technique

During subject matter analysis, SwRI researchers sought to identify the nature and shape of bodies of knowledge which the analysts must have in order to perform their jobs effectively. With subject matter analysis, SwRI attempted to draw out the details, shape, and relationships of what is known and done in order to do the job well. This information was then converted into representations of the optimals which are central to TNA. SwRI conducted a subject matter analysis through interaction with FSB analysts and managers, and through reviews of system documentation.

Detailed Methodology for Conducting the Study

Develop Data Collection Instruments and Strategy for Data Collection

During this project event, SwRI researchers met initially with Mr. Robert Hinson, the Software Development Section head, to strategize how the data collection effort would proceed. A decision was made that all of the analysts and managers in the Flight Software Branch would participate in the study. During this initial meeting, Mr. Hinson provided SwRI researchers with a high-level description of the work environment and tasks which were performed by the SSD analysts. Also during this initial meeting, SwRI researchers observed a Discrepancy Report (DR) Board meeting to observe analysts as they interacted with IBM contractors.

From the high-level description and observations, SwRI analysts developed interview survey instruments for the analysts and management (see Appendix C for copies of the survey instruments). These instruments were developed specifically for use by SwRI researchers as they conducted the interviews and observed the analysts in their work environment.

Conduct Surveys and Interviews

During this task event, SwRI researchers conducted two interviews with each SSD analyst and one interview with the two branch managers and branch chief.

Perform Task Analysis

After the initial interviews were conducted and preliminary reviews of the literature were completed, SwRI researchers developed a list of tasks performed by the analysts. The task listing appears in Appendix E, work environment description. The task listing was reviewed by Mr. Hinson, and the tasks were rated during the second structured interview with each analyst.

Conduct Statistical Analysis

Inferential and descriptive statistics were used to analyze the data collected during the needs assessment and subject matter analysis. The results of the analysis are provided in Appendix A.

Prepare Final Report

Upon completion of the site interviews/observations and an analysis of the data collected during the site visits, SwRI prepared a final needs assessment report.

APPENDIX G

SwRP's INSTRUCTIONAL SYSTEMS DEVELOPMENT MODEL

INSTRUCTIONAL SYSTEMS DEVELOPMENT

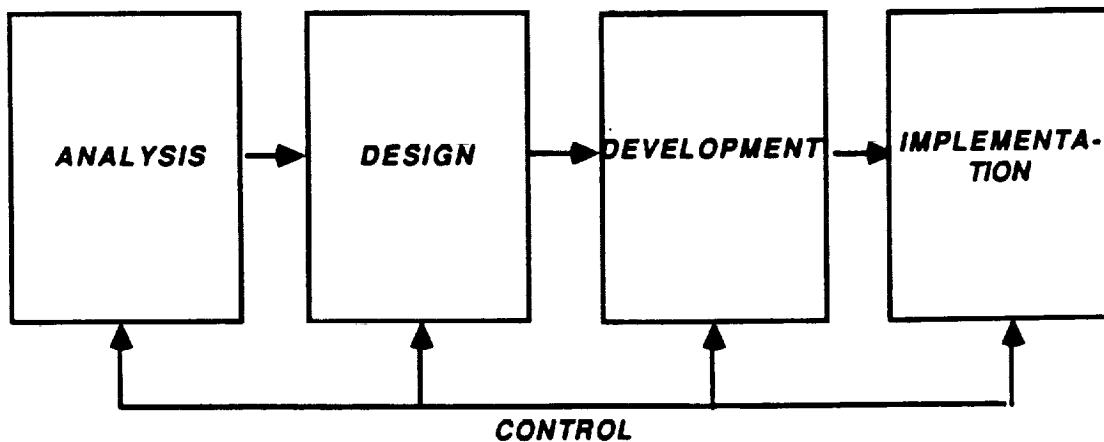
For 20 years, the military and the industry in the United States have successfully applied instructional systems development (ISD) in training. The ISD methodology is a process of quality planning, quality control, and quality improvement to ensure effective and efficient training. This paper presents a model of ISD that the Instructional Systems Section within the Training Systems and Simulators Department at Southwest Research Institute (SwRI) has adopted.

Overview of the Model

Instructional Systems Development applies a systems approach to solving problems of skill development within an organization. It is an orderly process for planning, developing, implementing, and evaluating instructional programs which ensure that personnel are taught the knowledge, skills, and attitudes essential for successful job performance.

The ISD model (Figure 1) divides the development process into five phases: analysis, design, development, implementation, and control. Typically, the first phase in ISD is to analyze the job along with any existing training to determine new training needs, i.e., what performance requirements are not adequately supported. In the design phase, the developers specify desired outcomes of the training including the instruction to be developed and implemented. Control is conducted at every stage through constant evaluation and revision of the process and product of training.

Instructional Systems Development (ISD)



INSTRUCTIONAL SYSTEMS DEVELOPMENT (ISD)

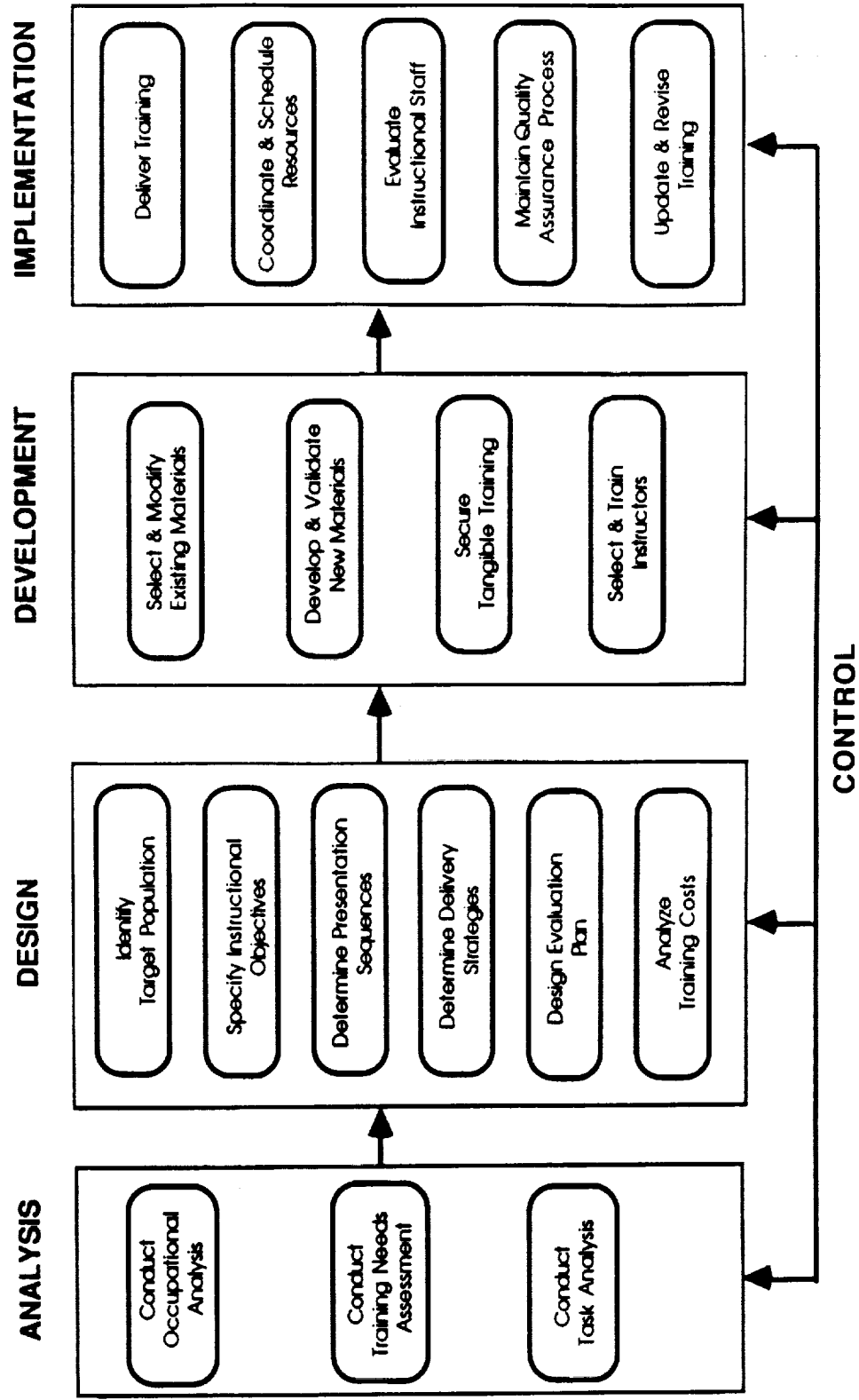
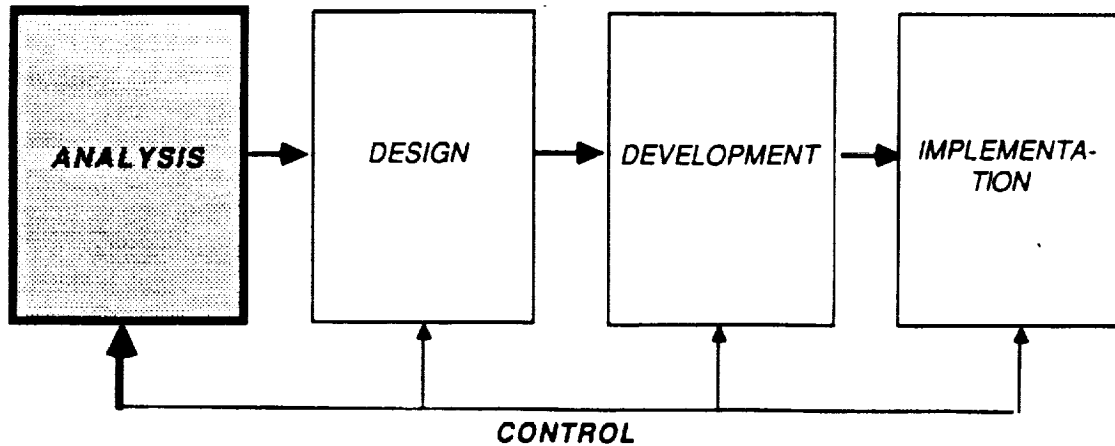


Figure 1. ISD: The Model

It cannot be overstressed how critical the analysis phase is to the success of the development process. In particular, the procedures used must identify all tasks performed in a job, all actions taken by the worker, and the acceptable standards of output or product. People must not rush into the phases of design and development with preconceived training needs and solutions if they expect the training they develop to match the job. Failure to identify critical tasks together with their correct performance requirements will produce incorrect or insufficient training and can result in bodily injury, equipment damage, and mission degradation. A careful and thorough analysis in the beginning will ensure that resources are not wasted on producing unnecessary or irrelevant training. Similarly, continuous evaluation of products throughout the process will allow for timely feedback and revision, and ensure a validated and effective program as the end product.

Each of the five phases comprises several steps. The rest of this report will describe in detail the steps in each phase.

Analysis



In this phase, the developers collect and review data on jobs, discrepancies between performance and requirements, current training, and task content. They investigate the following:

- What tasks do the trainees perform in their jobs?
- Which of those tasks need training? How much? In what format?
- What are the job performance requirements for the tasks selected for training?

Three types of analysis apply (see Figure 1.1). *Occupational analysis* identifies all jobs performed by the trainees and all tasks included in those jobs. *Training needs assessment* identifies what tasks require training, and where and how much is needed. Finally, a *tasks analysis* identifies the requirements for effective task performance (e.g., skills, knowledge, equipment, conditions, and standards).

Occupational Analysis

Occupational analysis is a procedure for the identification of jobs performed by all trainees and the tasks that comprise these jobs. To manage this process, SwRI has adopted the *Comprehensive Occupational Data Analysis Programs* (CODAP), which use the survey approach and are supported by computers. The CODAP is a well-established tool. Research and development of the system has been ongoing since the late 1950s.

The CODAP instrument collects demographic information from job incumbents and supervisors on questions of interest to management as well as task inventory data. The task data provide values for a number of factors used in the needs assessment to select tasks for training. The demographic information collected will be relevant to manpower and personnel problems such as projecting

INSTRUCTIONAL SYSTEMS DEVELOPMENT (ISD)

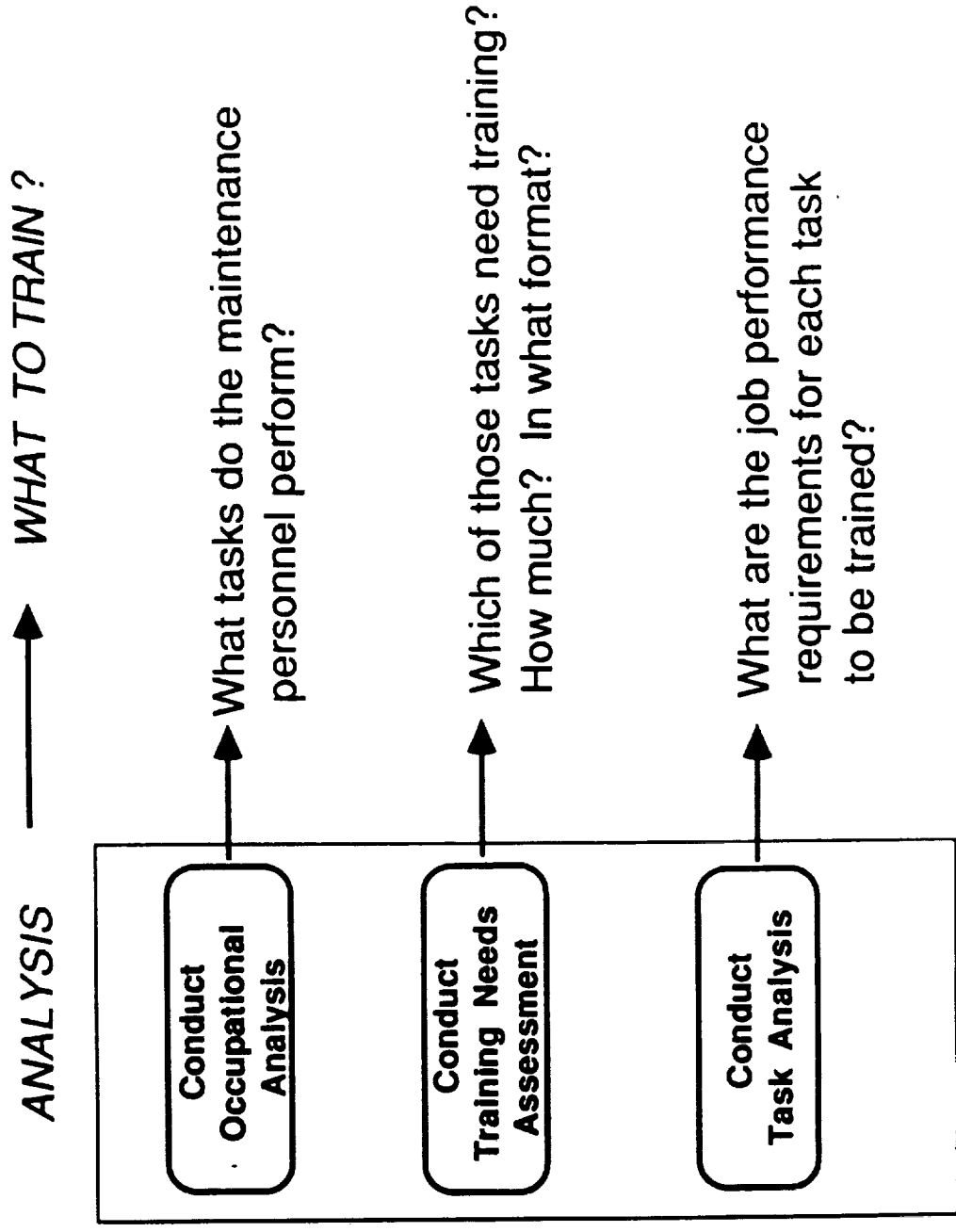


Figure 1.1 ISD: Analysis

adjustments needed to maintain a skilled work force when a significant proportion of experienced workers are approaching retirement. Also, when a need to redesign the career ladders surfaces, CODAP will allow multiple job series to be included in one survey. The system analyzes data obtained simultaneously from different work groups to reveal similarities and differences among the groups.

Among CODAP output, automated training indicators (ATI) are of particular interest to instructional designers. ATI is an index calculated for a task based on percentage of members performing it, its training emphasis, and task difficulty ratings. A training decision logic table has been designed to be used with ATI. For example, a task which is performed by a large percentage of employees and has high ratings of training emphasis and task difficulty gets a high ATI value. It indicates that formal knowledge and practical training should be provided for this task.

Although the CODAP program designs are as comprehensive as is possible at this time, they will not produce all the data required to complete the occupational analysis. Other methods such as work observation and focus group discussion may have to be used to supplement CODAP. Analysts often watch (and sketch or photograph) work in progress to verify actual task step details. Focus group discussion uses groups of eight to twelve people with a moderator using an interview guide to obtain expert opinions on a specific topic, such as subject matter experts' opinions on what training will be needed to accommodate a forthcoming technology change.

Training Needs Assessment

Using the complete task list generated in the occupational analysis, ISD analysts perform a needs assessment to ensure that some form of instruction will be provided for all the important tasks; and instructional resources will not be wasted. Some tasks may not require any training if all or most entry-level job holders can easily perform the tasks, and not all tasks require the same amount of training detail.

One product of the needs assessment will be identification of the appropriate instructional format. Options include:

- classroom training
- structured on-the-job training (OJT)
- self-study
- reference materials (e.g., job technical manuals, performance aids, and decision tables)

The selection depends on differentiating among tasks that need to be taught (instruction required), those that are too easy to need instruction (information required), those too rarely performed to justify training (reference material required), and those already well known by the target population (prerequisites). It is also important to identify when to offer what training (e.g., initial vs. refresher training).

The ISD model requires the analyst to identify the criteria used for establishing the need for training. Criteria may vary; but at a minimum, they will include the following:

- *Percentage of Members Performing the Task*

If a task is actually performed by most of the job holders, training is most likely to be justified.

- *Criticality of the Task*

The criticality of a task relates to the seriousness of the results of inadequately performing a task. Failure to perform a critical task correctly could result in injury or loss of life, damage to equipment, and significant mission degradation. A highly critical task, even performed by few, is the top training priority.

- *Task Difficulty*

Tasks relatively easy to learn on the job will need little or no formal training. For highly difficult tasks, a great deal of formal training may be required.

- *Frequency of Task Performance*

A task that occurs rarely will not have a high priority for training unless it has been identified as having critical consequences.

- *Time Interval before Initial Job Performance*

If analysis shows a large time interval between formal training of a certain task and the first time that task is performed on the job, options should be considered, such as postponing formal training to a later stage of the training curriculum or offering periodic refresher training sessions to reinforce retention and skill proficiency.

The output of the Training Needs Assessment is a list of all job tasks selected for training together with information such as when and in what format training will be conducted.

Task Analysis

Task analysis determines the content of the training. Information includes:

- activities required to accomplish a task and their sequences
- skills, knowledge, attitudes, and physical requirements associated with the activities
- the equipment and materials involved with each task
- conditions/environment under which these tasks are performed
- standards for successful performance
- safety requirements

Sources of data include:

- observing tasks being performed
- interviewing novice and experienced performers and supervisors

- reviewing technical documentation for the tasks
- reviewing effectiveness data on current and previous training

Results of the detailed content analysis for each task to be trained provide input into developing objectives and tests, defining training content, determining structure and sequence, and identifying appropriate training methods and media.

Output of The Analysis Phase

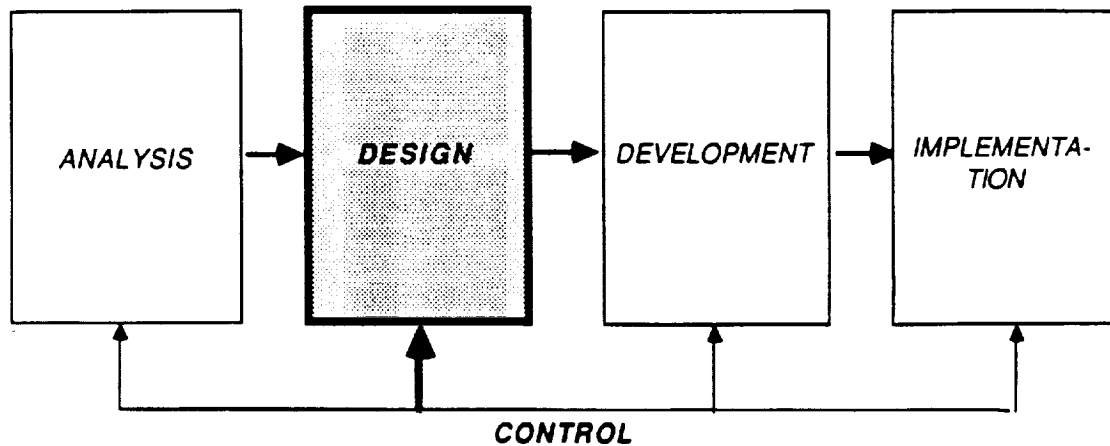
The end-product of the analysis phase is a set of training recommendations including the following information:

- tasks identified for training
- training formats, such as formal training, OJT, job aids/reference materials, periodic updates, and self-study, for each task
- detailed specifications of job performance requirements, including skills/knowledge, physical requirements, equipment, conditions, and standards, for each tasks.

Quality Control

To make sure the analyses use accurate and unbiased data, obtain information from a wide variety of sources, always checking one source of information against another.

Design



This phase addresses the elements that define the training approach. It begins with assessing the target audience. Then, learning objectives are defined and sequenced; and methods, media, and evaluation approaches are specified (see Figure 1.2).

Identifying the Target Population

Knowing the entry level skills of the target population is critical in developing effective training. The starting point for training depends on what the trainees already know. Target population characteristics will influence both the design and the delivery of training.

Job Skills

Prerequisite skills that trainees already possess need to be specified to attain a homogeneous target population and eliminate the need for offering very basic courses to level out major differences. Nevertheless, different trainees possess different skills and different degrees of proficiency. Therefore, it is useful to identify each trainee's profile of job-related skills to minimize mismatches that would teach a trainee something he or she already knows or attempt to teach material he or she is not prepared for.

To assess skill profiles, a global diagnostic test or a series of course-specific bypass tests can be used. A diagnostic test evaluates each trainee on the proficiency of *all* skills covered in the job. A bypass test, on the other hand, evaluates *only* skills covered in one course. Students only need to take the global diagnostic test once, and results give a relatively holistic picture of a trainee's skill profile. Bypass tests, on the other hand, kill two birds with one stone — once the bypass tests are

INSTRUCTIONAL SYSTEMS DEVELOPMENT (ISD)

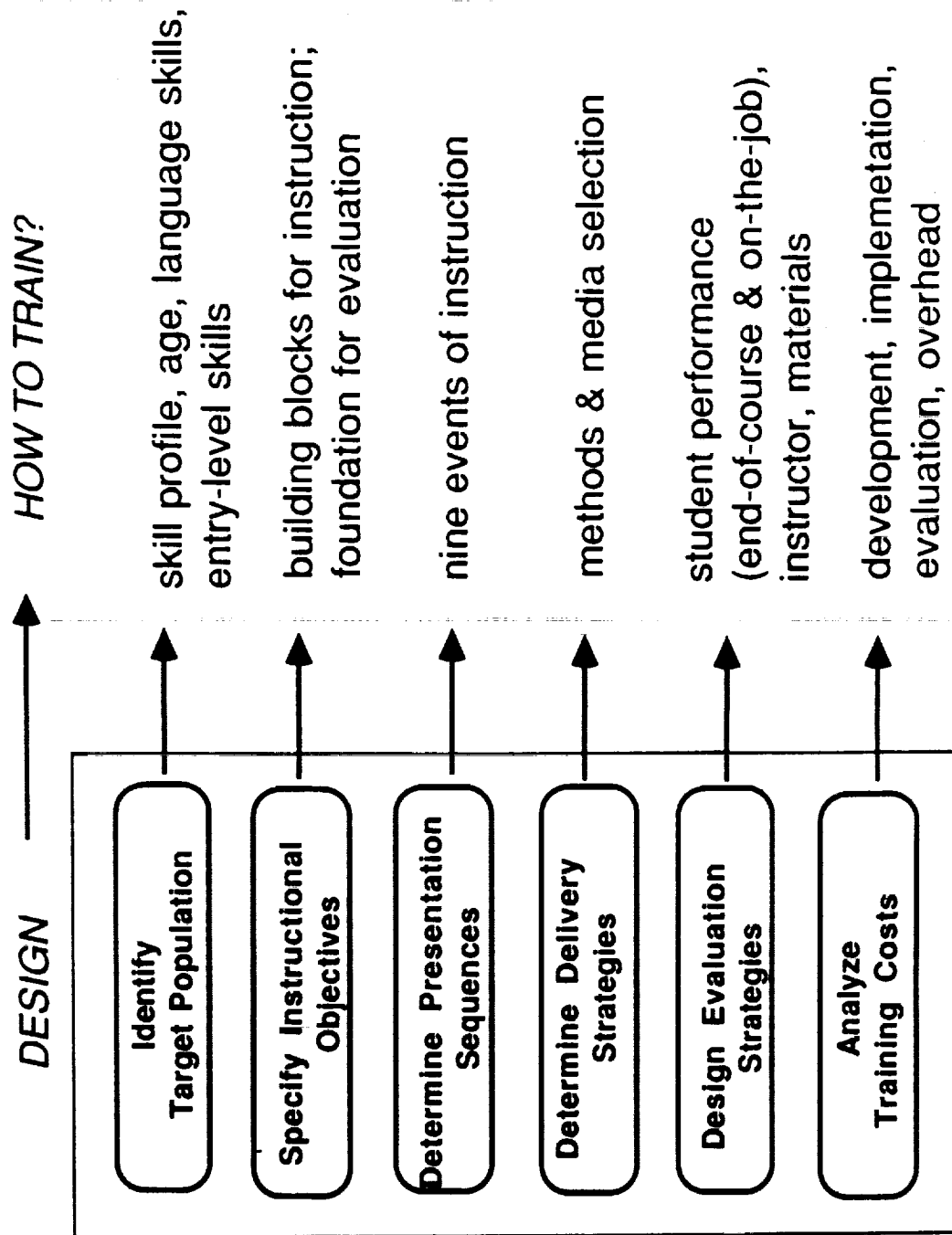


Figure 1.2 ISD: Design

developed, they will serve as end-of-course performance measures, which must be prepared anyway. Whichever is selected, the test(s) must be validated before use.

In addition to the test(s), a supervisor's assessment and recommendations about a trainee should also be considered. For a supervisor to make accurate recommendations, a detailed description for each course in the training curricula is essential, which includes detailed information of instructional objectives, content outline, and entry-level skills/knowledge (see *Output of the Development Phase* for details). Without this information, supervisors are less likely to make appropriate recommendations.

Language Skills

The reading level of the target population must be established for written training development. Instructional materials must be written at trainees' reading level. Otherwise, language skill requirements should be imposed in the personnel selection process to screen out unqualified applicants. This approach is not recommended where language skills cannot be shown to be a job requirement (rather than a training requirement).

Specifying Instructional Objectives

An instructional objective is a precise statement of the knowledge and skills that the students must master. It describes what students will be able to do after instruction. A complete statement of an objective specifies the desired performance, the minimum standard of performance required, and the conditions under which the behavior is exhibited. The information is derived from data in task analysis.

When properly stated, objectives will be able to serve as the basis for selecting appropriate instructional methods and media, detailing instructional content, and developing a valid evaluation plan and instruments. When clearly communicated to the learners, objectives prepare them for the training and focus their attention on the important content.

Supporting Objectives

Each instructional objective is reached through a series of supporting objectives. Supporting objectives are intermediate steps toward a terminal objective. Some of them are included in the task being taught, and others are presumed to be prerequisites. Since prerequisites are not covered in instruction, they can be used to screen the target population of the course. Alternatively, the learning objectives may be revised, or optional basic courses (formal or self-study) may be offered to new employees.

Classification of Objectives

Human learning can be classified into the following five categories:

- *verbal knowledge* stating information

- *intellectual skill* using concepts and rules to solve problems; responding to classes of stimuli as distinct from recalling specific examples
- *cognitive strategy* originating novel solutions to problems; utilizing various means for controlling one's thinking/learning processes
- *motor skill* executing bodily movements smoothly and in proper sequence
- *attitude* choosing to behave in a particular way

Each category of learning requires different types of instruction. For the purpose of prescribing appropriate instructional treatment, it is important to classify objectives into these categories.

Determining Presentation Sequences

Presentation of content should follow these guidelines:

- proceed from the known to the unknown.
- proceed from the simple to the complex.
- proceed from the concrete to the abstract.
- proceed from observation to reasoning.
- proceed from a whole view to a more detailed view to a whole view.

Each instructional unit should also contain the following nine events of instruction to ensure that desired learning outcomes occur.

- 1) Obtain learner's attention
- 2) Inform learner of the objectives
- 3) Stimulate recall of prerequisites
- 4) Present the information
- 5) Provide learning guidance
- 6) Elicit performance
- 7) Provide practice and feedback
- 8) Assess performance
- 9) Enhance retention and transfer

Determining Delivery Strategies

After instructional objectives have been written, the next step is to select appropriate delivery strategies — that is, instructional methods and media — to achieve the desired learning outcomes. Methods are procedures or processes. Media are means by which those procedures or processes are expressed. Examples of methods include the following:

- presentation
- demonstration
- drill-practice

- tutorial
- gaming
- simulation
- discovery
- problem-solving

Examples of media are:

- print
- audio tape/slides
- overhead transparencies
- filmstrips
- films
- mock-ups
- videotapes
- computer/interactive videodiscs
- part-task trainers
- simulators
- telephone
- TV
- satellite

Media, depending on their design and capabilities, can be stand-alone or supplementary to classroom instruction. For example, some tasks may be taught in their entirety using a computer-based training (CBT) program. A CBT program can also support stand-up instruction. Different methods and media can be used to accomplish the same instructional objectives. Selection of the most appropriate method or medium, however, depends on many factors.

The decisions involving methods and media selection are interrelated and should be made concurrently. However, for the convenience of explanation, they are discussed separately below.

Instructional Methods Selection

The selection of appropriate instructional methods depends on three factors: types of objectives, stages of learning, and instructional settings.

Types of Objectives Earlier it was mentioned that objectives can be divided into five categories. These categories include: verbal information, intellectual skill, cognitive strategy, motor skill, and attitude. Each of these categories requires different considerations in the methods selection decision. If an objective involves attitudes, the use of human modeling is usually appropriate and effective. For verbal information, on the other hand, straight presentation and practice of recall may be adequate.

Stages of Learning Any method of instruction can be used at any stage of learning, but some are more appropriate for one stage than another. For example, during the early stage of learning a skill that involves great danger, demonstration and simulation may be more appropriate than the drill and practice method.

Instructional Settings Training can take place in a large-group, small-group, individualized, or teletraining setting (where the instructor is physically separated from the learners). Large-group training may be less expensive; however, it does not accommodate individual needs. On the other hand, small-group and individualized settings cater to individual needs, but they are also more expensive. Therefore, when cost is the primary concern or when the instructional objective is solely the delivery of information, large-group may be considered. Otherwise, consider small-group or individualized.

Further, when the target population is geographically dispersed, it may be more cost effective to deliver training via teletraining than to bring all the trainees to a centralized location. Teletraining is also effective for providing updates and refresher training.

In selecting methods, the instructional setting needs to be considered. For example, drill/practice and tutorial lend themselves to a small group or individualized setting while presentation or demonstration is more appropriate for a large-group setting. A combination of demonstration via videotape and locally supervised drill/practice may be appropriate for skill training.

Instructional Media Selection

The selection of appropriate instructional media depends on such factors as size of the target population, level of resemblance to the job, stability of task content, instructional methods, learner characteristics, media capabilities, resources/logistical requirements, and costs.

Size of the Target Population The number of trainees can determine the cost-effectiveness of using a particular medium. For example, if an instructional unit will be offered repetitively to a large number of trainees, computer-based training such as interactive videodisc may be more cost effective than a live instructor since the cost will be scaled down with mass production.

Level of Resemblance to the Job Generally, it is best to have the instructional situation as similar to the job situation as possible. However, high cost, safety, and limited resources often prevent the use of actual job environment. In general, tasks that require concrete actions (e.g., remove and install an engine) benefit from a realistic learning environment on simulation. Tasks with abstract information (e.g., compute budget estimates), on the other hand, require a less realistic learning situation.

Stability of Task Content Updating training materials can be as costly as developing new ones. For example, it may not be cost effective to develop an expensive interactive videodisc program to teach tasks requiring constant updates.

Instructional Methods Limited by presentational capabilities, certain media can only convey certain methods. For example, intelligent tutoring systems (e.g., intelligent computer-assisted instruction, interactive videodisc, expert system, etc.) are great tools for drill/practice, simulation, and problem-solving methods. Print material, on the other hand, is an efficient and cost-effective way to deliver straightforward information. It would be a waste of resources to use an intelligent tutoring system for the sole purpose of presenting information.

By the same token, print material, though less expensive to produce, would not be appropriate if practice of physical skills is involved.

Learner Characteristics To select media, the following questions regarding the target population need to be answered:

- What is the range of the target population's reading level?
- Is the target population computer-literate (if the computer will be used)?
- How comfortable is the target population with a particular medium?

In other words, literacy is the key word. If a sophisticated medium is selected, practice must be provided for learners to become comfortable with that medium.

Media Capabilities Media range from still visual (flip charts, overhead transparencies, printed text, etc.), still visual with audio (synchronized audio tape/slides), motion (videotape, film), to highly complicated computer-based training, IVD, and simulators. Each medium offers different capabilities of presentation. If visual recognition is involved, or if the use of visuals will enhance recall of the content, media with visual capability are helpful. A combination of media is often desirable — e.g., a videotape and a workbook, or overhead transparencies used in conjunction with a classroom instructor.

Another way to categorize media is by the level of interactivity a medium allows between the source of instruction and the learner. With media like textbooks, film, videotape, and TV broadcasts, the information flow is one-way, from the instructional source to the learner. On the other hand, intelligent tutoring systems such as CBI and interactive videodisc are highly interactive in the sense that they are able to provide immediate feedback to the learner and, in some cases, prescribe individualized instructional treatment. Interactive media tend to be expensive to produce, but as mentioned above, they become cost effective with use by large populations over time. Trade-offs need to be made considering capabilities of the media, the criticality of the task, and budget.

Resources/Logistical Requirements The availability of resources required to develop the program is an important selection factor, as are costs required to deliver, maintain, and update the training materials.

Resources for consideration during media selection process include:

- **Equipment:** instructional support
- **Facilities:** classrooms
labs
- **Manpower:** instructors
subject-matter experts
instructional designers
material production crew
administrative support staff

- Time for development

Costs Two kinds of costs are involved in training programs, development costs, and running costs incurred during use. The cost per student of a presentation diminishes as the number of students using it increases. Some media with high development costs but lower running costs may in the long run be more cost effective.

Designing Evaluation Strategies

Evaluation is crucial in the success of the ISD process. Without evaluation, the effectiveness of a training program cannot be demonstrated and training costs cannot be justified. Although the actual effectiveness of an instructional program cannot be determined until it has been implemented, it is important that evaluation strategies are planned out at the design stage.

Assessing Student Performance

The ultimate goal of evaluating an instructional program is to find out whether instruction results in *desired knowledge/skill gain* and, more importantly, *improved on-the-job performance*. Written tests are usually the instruments used to evaluate knowledge gain. Performance measures, on the other hand, commonly require the student to execute a task to demonstrate his or her mastery of the performance objectives. Whichever is used, instructional objectives are the basis on which to design these instruments.

Assessing on-the-job performance (i.e., how much the skills are transferred to the job) is more complicated. It usually involves observing a trainee at work in a real-job situation and interviewing the trainee's supervisor.

Assessing Instructors, Media, and Student Materials

In addition to student performance, other elements to look at to assess the quality of an instructional program are:

- instructor
 - subject matter expertise
 - presentation skills
 - media utilization skills
 - instructional management skills
- medium
 - relevancy of objectives
 - accuracy of information
 - technical quality
 - pacing
- student materials
 - textbooks
 - reference materials (job aids, decision tables)
 - handouts

other supplementary materials (organization, language level, etc.)

Sources of data are students, subject-matter experts, instructional designers, and media experts. Surveys, observations, and interviews are common methods of data collection. This assessment can be useful in identifying weak points in an instructional program in order to pinpoint needed revisions.

Analyzing Training Costs

The costs associated with training include:

- | | | |
|---|----------------------|---|
| ■ | Developmental Costs | production
equipment
materials |
| ■ | Implementation Costs | equipment
materials
facilities
instructional staff
student training time
travel
operation/maintenance |
| ■ | Evaluation Costs | evaluators
materials
equipment |
| ■ | Overhead | administrative support |

Some guidelines for estimating training costs are suggested:

1. Look at training costs in terms of the salary and loss of productivity of the learner while in training. The monetary value of the time spent by learners usually makes up the largest part of training costs — typically 80%. Learner training time is the single most significant training expense — not program development costs. These costs, however, may be offset by improved job performance.
2. Use "full costs per hour" to estimate the labor costs of a training project. Full labor costs take into account salary or hourly wages plus all fringe benefits.
3. To complete an analysis of labor costs, estimate the time spent on developing a state-of-the-art training program, or compare supplier price estimates with internal costs. The following are useful, though far from hard and fast, development time ratios:
 - 15-40 hours of development time produce one hour of instructor-led delivery.

- Between 40 and 110 hours of development are required to produce one hour of completed video. (Typically, industrial costs for outside-supplied videotape run from \$1,000 to \$2,000 per finished minute.)
- Approximately 100 to 400 hours of development result in one hour of computer-based training program.
- Between 200 and 1,000 hours or higher of development produce one hour of interactive videodisc training program.

More complicated learning processes require additional development time. Instruction that involves synthesis, application, or problem-solving is more costly than instruction that calls for recognition or recall.

To prepare a training budget or to estimate program costs, a spreadsheet application is recommended. Using a spreadsheet allows changing of variables and values for estimating purposes. Notice that the spreadsheet totals the costs for each step of the program: analysis, design, development, delivery, and evaluation.

Output of the Design Phase

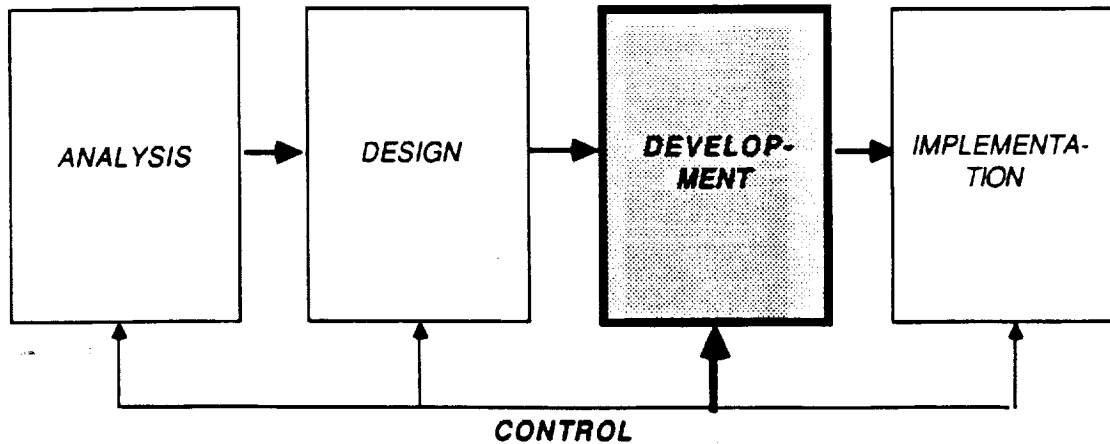
The output of the design phase will be documents that specify

- the instructional objectives
- the course structure (modules, lessons, courses) and the content sequence
- the delivery strategies (methods and media)
- the evaluation plan

Quality Control

To make sure that sound design decisions are made, the entire process needs to be monitored with care. Criteria will be developed to assess the quality and completeness of each design document. A Quality Assurance Group, composed of subject matter experts, instructional designers, and managers, will be formed. Each major design decision will be defended or justified with rationales to the members of this group.

Development



The development phase is where the actual production of the training course takes place (see Figure 1.3). The process usually involves both selecting/modifying existing materials and developing new materials. Obtaining tangible vendor training at the time of major equipment purchase can meet part of the requirement.

Selecting Existing Materials

When selecting off-the-shelf instructional material, check off the following criteria:

- Does the material match the instructional objectives in the design phase?
- Does the target population have the prerequisites (reading ability and vocabulary level are often important)?
- Is the information accurate and up to date?
- Is the presentation likely to arouse and maintain interest?
- Does it promote active involvement of learners?
- Is the technical quality acceptable?
- Has the material demonstrated its effectiveness, such as in field tests?
- Is it free from bias?

It should be noted that different criteria are suitable for different situations. It is up to the instructional designer to decide which criteria are the most important.

INSTRUCTIONAL SYSTEMS DEVELOPMENT (ISD)

DEVELOPMENT → OBTAIN TRAINING

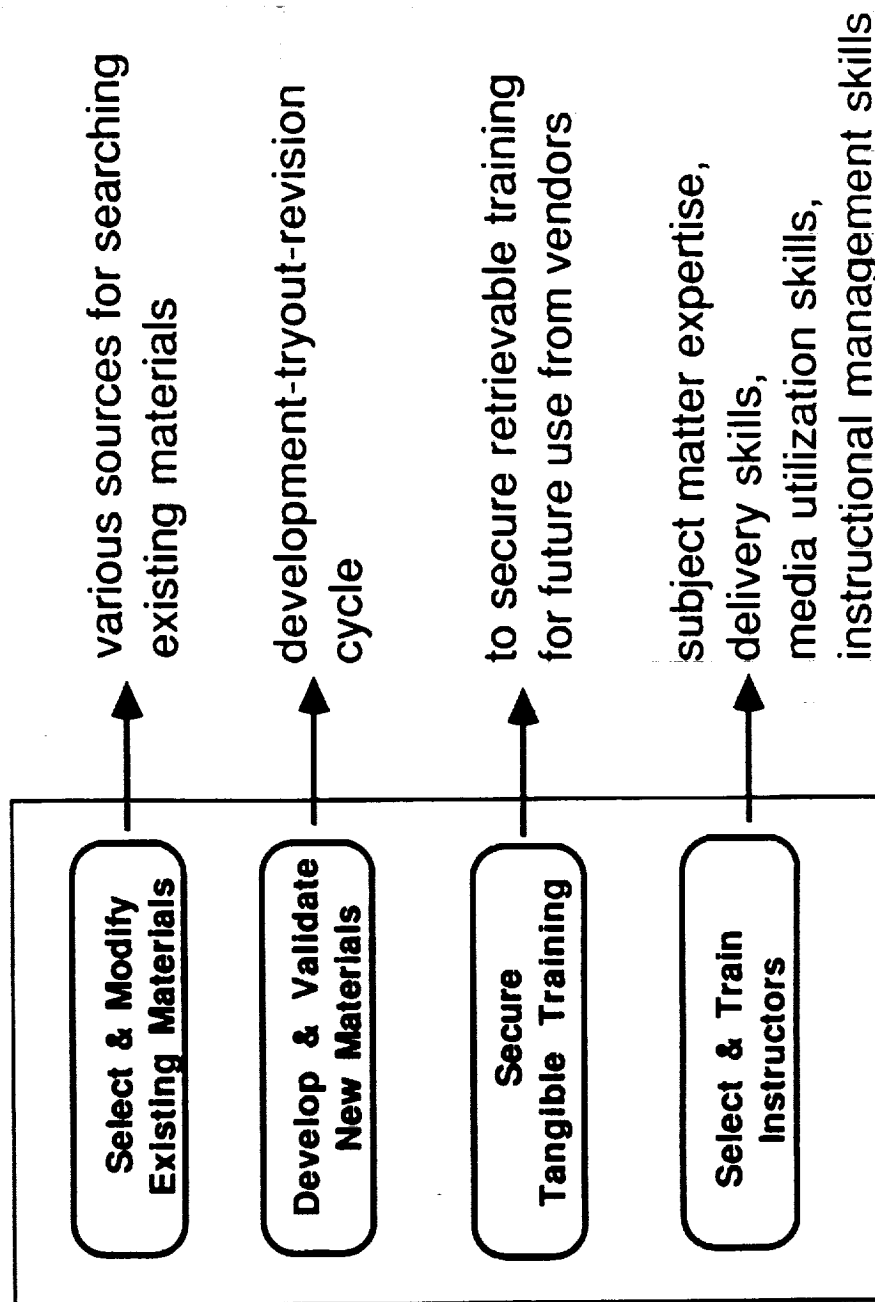


Figure 1.3 ISD: Development

Developing New Materials

Experienced instructional developers work within the requirements of the chosen delivery media to tailor instruction to the terminal and supporting objectives specified in the course design. Materials produced usually include such items as instructor and student guides, course outlines, instructional content, tests, and remedial sequences. Formats will depend not only on media but on such factors as whether the course is classroom or self-instructional, drill and practice or simulation, process or product based.

Developing Evaluation Instruments

Following the evaluation specifications from the design stage, test items for each courses, checklists for skill performance, survey questionnaires, and observation recording sheets are developed. The tests need to be validated to ensure they measure the appropriate performance.

Validating Instructional Materials

The developers conduct formative evaluations during development to make sure that the instructional products meet all the instructional requirements specified in the design phase. Data collected are used to revise and improve the product under development. The advantage of this process is to detect errors in design and development while it is still possible to correct them. In this process, the instructional product is tried out by students sampled from the target population. Instructional designers and media experts will also examine the product. The development-tryout-revision cycle goes on until the students can meet the performance standards.

Procurement of Tangible Training

When new equipment or hardware is purchased, vendors normally provide some training, which is usually not documented in a tangible form such as training manuals or computer-based instruction. Once vendors fulfil their contracts and withdraw, there is no way to retain the training for future use. However, providing ISD-based training materials can be included in the procurement contract. This would enable the buyer to be self-sufficient in future training. Requirements for tangible training must be specified in the Request for Proposals for the equipment (see *Output of the Development Phase* for details).

Obtaining Qualified Instructors

A qualified instructor should have the following competencies:

- subject matter expertise
- delivery skills
- media utilization skills
- instructional management skills

Qualified instructors can be obtained through careful screening and/or training. Instructor preparation is especially important when unconventional instructional methods and technologically advanced media are used.

Output of the Development Phase

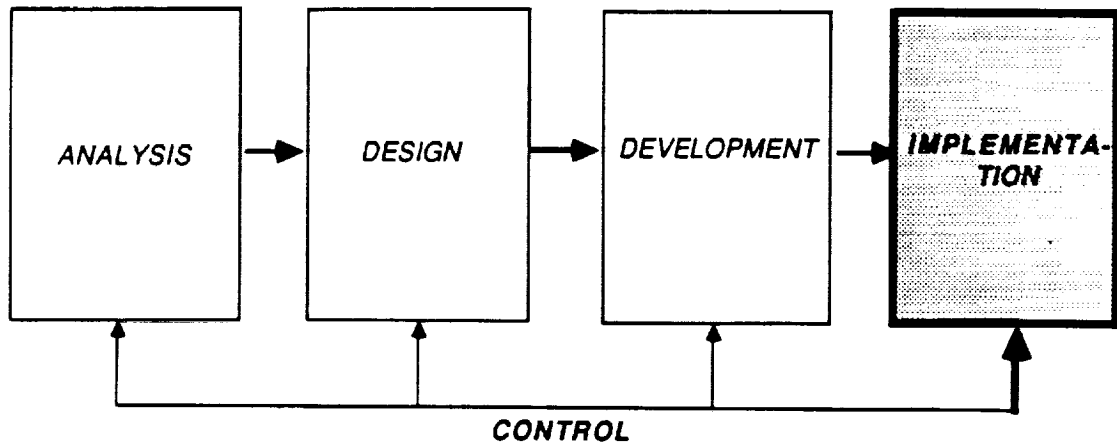
The end-product of the development stage may include most or all of the following components:

- Detailed Course Description
 - . instructional objectives
 - . target audience (skill profile, language skills, etc.)
 - . format of training (OJT vs. formal training, resident vs. nonresident, group-based vs. individual-based, teletraining vs. traditional, etc.)
 - . prerequisite skills/knowledge
 - . content outline
- Student Materials
 - . textbooks
 - . workbooks
 - . handouts
 - . self-study guide
 - . reference materials (e.g., manuals, job aids, decision tables)
- Instructor's Guide
 - . instructor's requirements
 - . lecture notes
 - . media utilization tips
 - . equipment, facilities, and scheduling information
- Instructional Material
 - . mediated programs (such as videotapes, computer-based training, etc.)
 - . instructional activities (question and answer, group discussion, etc.) and their duration and sequence
 - . drill/practice, assignments and quizzes
- Evaluation Plan and Instruments
 - . written measures (tests) and performance measures (checklists) for evaluating student end-of-course performance
 - . instruments for overall assessment of the package (the instructor, media, student materials, etc.) by both students and instructional designers
 - . follow-up evaluation plan and instruments for assessing on-the-job performance

Quality Control

A complete list of criteria should be generated against which each instructional product, selected or newly developed, will be evaluated. Again, a Quality Assurance Group may be one good means to approve instructional materials.

Implementation



Issues to be addressed at the implementation stage include:

- delivering instruction as designed
- maintaining the quality of instruction
- evaluating and improving the instructional staff
- scheduling training to meet the demand
- maintaining sufficient resources (manpower, facilities, and equipment)
- monitoring the effectiveness of training to identify necessary revisions and updates

As for any organizational change, the most critical factor for successful implementation of an instructional system is top management commitment. Managers must become believers in the ISD concept. This means insistence upon a good, detailed front-end analysis and a strong conviction of the importance of the quality control process.

Output of the Implementation Phase

The output of this stage includes:

- Coordination/scheduling of resources to meet training demands
- Qualified/trained instructional staff
- Delivered training
- Evaluation data (both short-term and long-term) collected
- Revisions made to maintain the effectiveness of training

INSTRUCTIONAL SYSTEMS DEVELOPMENT
(ISD)

IMPLEMENTATION —→ DELIVER & MAINTAIN TRAINING

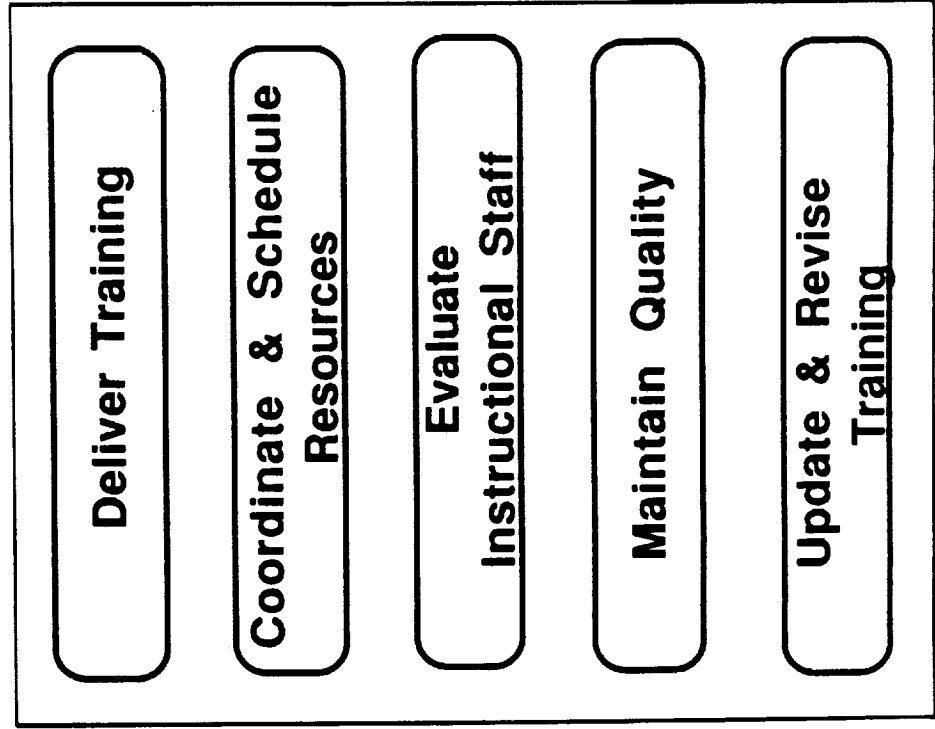
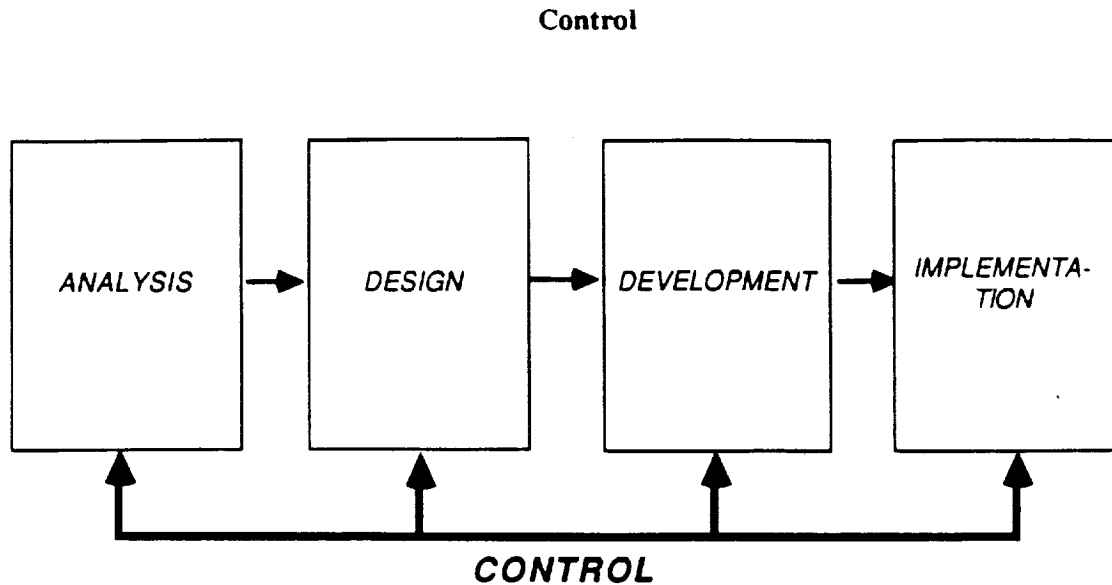


Figure 1.4 ISD: Implementation

Quality Control

The Quality Assurance Group can be used in monitoring and maintaining the quality of the program during implementation. This group makes sure that training is delivered the way it is supposed to be, and the evaluation-revision loop is established.



The control component of ISD is a quality assurance mechanism that involves a third-party validation of the analysis, design, development, and implementation of training with the purpose to improve instruction. Control requires the process and product of training to be constantly evaluated. Information collected from the evaluation is then fed back to the system to revise instruction. The evaluation-revision loop is essential to the quality of any training program. For example, if instructor performance data are not looped back to instructors, they cannot know how well (or how poorly) they have performed; and therefore, they will not know how to improve their teaching. If student performance data (both end-of-course and long-term on-the-job performance) are not analyzed, the design team will not know which part of instruction needs revision.

The Quality Assurance Group

To ensure the establishment of the evaluation-revision loop, a Quality Assurance Group must be formed. This group is composed of instructional designers, subject matter experts, managers, instructors, media specialists, apprentices, and experienced job holders. Periodically, group members will review the evaluation data to see if the effectiveness of training is deteriorating. If so, investigations will be launched to identify the problems — the content may be outdated, the target population may have changed, instructors may not be qualified, wrong skills may have been addressed, or some environmental factors may exist that have interfered with learning. After problems have been identified, the design team is required to revise or redesign instruction.

To stay objective, the Quality Assurance Group should be independent of the course/curriculum development team. That is, members of this group are not involved in the development of training, so they can look at instruction with fresh and unbiased eyes.

The Quality Assurance Group monitors not only the product but also the process. During the analysis phase, they make sure that data collected are complete and unbiased, and training recommendations are made on justifiable grounds. During the design phase, the Group reviews each design document on its soundness, completeness, practicality, and feasibility. It may require the design team to provide rationales behind each design decision (e.g., why computer-based training is selected over stand-up classroom lecture). During the development phase, Group members make sure that instruction (selected, modified, newly developed, or procured from vendors) meets the design specifications. If it is found that certain design specifications are not feasible, they see to it that best alternatives are considered. Furthermore, whether instruction is developed in-house or by an outside contractor, the Group will ask to see hard evidence of the effectiveness of the product (e.g., from a field test). Finally, at the implementation stage, the Quality Assurance Group constantly oversees training to make sure that it is properly delivered, instructors are well prepared, equipment and facilities maintained, and timely updates made.

With the evaluation-revision loop (or control), the development and delivery of training are constantly monitored and necessary measures are taken to fix the problems. Facilitated by the Quality Assurance Group, this mechanism maintains the quality of instruction and keeps training up to date.

Summary

To summarize, this report has described a systems approach to the development of training. The five basic components, together with their subordinate steps, represent the procedure one employs to ensure effective training.

At the *analysis* phase, occupational analysis, training needs assessment, and task analysis are conducted to identify when, where, what, and how much training is needed. These analyses yield information concerning training curricula/paths, prescription of training formats for different tasks, skills/knowledge to be trained, and job performance requirements.

At the *design* phase, instructional objectives are defined; and media selection is made. Evaluation plans for assessing the effectiveness of training are specified including end-of-course assessment and long-term on-the-job performance appraisal.

At the *development* stage, instructional materials are produced and validated before they are used. Validation is a process that reiterates the development-tryout-revision cycle until the product proves effective.

The *implementation* stage addresses the issues of delivering training and maintaining the quality of training. Upper-level management support is a must for the success of any training programs.

The *evaluation/revision* loop (control) is a quality assurance mechanism that involves a third-party validation of the analysis, design, development, and implementation of training. A Quality Assurance Group may be used, which is composed of managers, instructors, instructional designers, experienced job-holders, and apprentices. Periodically, members of this group will collect and review evaluation data to identify deficiencies in the training system. Revisions will then be made to improve the programs.

In conclusion, application of the systems approach to training development will result in improved job performance, elimination of unnecessary training, greater use of various training formats, and improved training efficiency.

APPENDIX H

RELEVANT RESEARCH

APPENDIX H

REVIEW OF RELEVANT COGNITIVE LEARNING RESEARCH

SwRI's solutions to identified needs are supported by cognitive-based instructional theories which have been hypothesized by different researchers over the last thirty years. The researchers have conducted experiments which empirically validated the theories. From this research, a wide variety of discoveries have been made about cognitive functioning. The following section summarizes conclusions from theoretical studies associated with adult cognition which specifically relate to the needs assessment and solutions recommended in this study.

Interactive Training

Although opinions vary among learning theorists as to what internal processes occur as an individual learns, there is considerable agreement that certain conditions improve learner performance. These conditions include active participation, practice, feedback, repetition, and motivation. Studies have also shown that information taken in through multiple senses is more readily learned than through a single sense.

Interactive training (such as computer-based interactive videodisc) offers the learner an opportunity to respond to stimuli and to receive almost immediate feedback, reinforcement practice, and remediation as required. According to Fleming and Levi (1978), the core feature of the technology - interaction - is based on a sound educational principle:

In general, where the learner reacts to or interacts with the criterial stimulus, learning is facilitated and that facilitation increases with the degree of learner activity or involvement.

There are other message design principles available with interactive videodisc training simply by the nature of the medium:

- Words and pictures promote better retention and learning than words alone
- Concepts about concrete objects are more readily learned than concepts about abstractions. Observing the attributes of a concept from an image and then distinguishing them visually from nonattributes (features not related to the concept) helps a person learn and remember the concept
- Observing a person performing some activity and then modeling the observed behavior is a very powerful instructional approach, especially for teaching problem solving

More learning occurs as the user's involvement with the prepared materials deepens, from simple attending (reading, looking, listening) to covert responding (repeating words subvocally) to overt responding (concrete actions). A well-designed, high-quality interactive training program encourages learners to produce more intense, overt responses.

Spatial Representation of Information

A number of training researchers have recognized an overemphasis on verbal skills and lack of emphasis on visual skills in modern education and training. These researchers have suggested that imagery and spatial ability skills be included in instructional design endeavors (Hotin, 1982; Galin and Ornstein, 1979; Schroeder, 1980). Several recent studies indicate that providing subjects with a visual representation enhances learning and performance on some tasks. In a research program investigating individual differences in spatial/verbal cognitive ability, Schroeder (1988) showed that there was a general performance superiority for subjects receiving spatially-augmented information.

Individuals in training programs are often not provided with conceptual overviews of the entire discipline or system they are studying. Instead, training segments are often fragmented and targeted for task-specific training objectives. Some students form mental models of the system from the fragments they have learned; however, when such abstraction is left up to the individual there are no guarantees that their model will be technically accurate.

Spatial representations lend themselves to conveying general organizational information. While verbal descriptions can be created to describe system relationships, spatial representations can often be more precise and meaningful.

Hierarchical Structuring of Instructional Content

Cognitive psychology has recognized that the brain of the learner is the active agent in information acquisition rather than the passive receiver (Shriver, 1984). Instructional theorists such as Bruner (1956), Ausubel (1968), Anderson (1976), Norman (1975), Bobrow (1968), Reigeluth (1983), and Merrill (1983) discuss the effects of cognitive structures believed to reside within the learner on acquisition and retention of knowledge. They assume a hierarchical organization of knowledge in memory from abstract and general to concrete and specific. They also assume that semantic similarity is the basis for the linkages with which the information is related within a knowledge structure. Networks or schemata are the terms used by researchers to refer to the units of knowledge created by means of these linkages.

The two major theorists in hierarchical structuring of instructional development are Ausubel (1968) and Gagne and Briggs (1974). These two theories are addressed below.

Ausubel's Meaningful Reception Learning and Retention

Ausubel is primarily concerned with meaningful reception learning and the acquisition and retention of bodies of knowledge. Ausubel makes a distinction between reception learning, rote learning, and discovery learning. Rote learning involves memorization of arbitrarily associated bodies of information for which the learner lacks relevant prior knowledge. Discovery learning, involves the presentation of specific instances from which the learner must discover what is to be learned. In reception learning, the "what is to be learned" is presented to the learner in its final form.

Ausubel advocates the use of advance organizers in instructional development. The advance organizer provides both an overview of the more detailed information to be presented in the instruction, and a scheme or organizing elements that will incorporate the new material into a person's memory (cognitive structure). The advance organizer's principal function is to "bridge the gap" between what the learner already knows and what he needs to know to learn the task at hand.

Ausubel also recommends the use of comparative organizers to integrate new ideas with basically similar concepts already in a person's cognitive structure and to increase a person's ability to discriminate between new ideas and existing ideas that are essentially different but appear confusingly similar.

With Ausubel's theory, instructional material is organized by first presenting the more general, more inclusive ideas followed by more specific and less inclusive ideas. Going from the "top of the pyramid to the base." This process is called progressive differentiation.

Gagne's Conditions of Learning

Gagne emphasizes the internal and external conditions of human learning. These conditions are derived from research on learning and learning efficiency. The conditions for learning are explicated by an information processing model of learning and memory (a model which is employed by a number of modern learning theorists). This model incorporates a sequence of internal processes involved in each act of learning and five different kinds of memory organizations which

are internally stored as a result of learning and which exhibit themselves as types of human capabilities (or "learning outcomes"). Both of these sets of internal conditions carry implications for the external conditions of learning.

The input variables (instructional events) to Gagne's theory are:

1. Gain the attention of the learner
2. Inform the learner of the objective
3. Stimulate recall of prerequisite learning
4. Present the stimulus material
5. Provide "learning guidance"
6. Elicit performance on the part of the learner
7. Provide feedback about performance correctness
8. Assess the performance
9. Enhance retention and transfer

APPENDIX I
REFERENCES

REFERENCES

- Alessi, Stephen M., and Trollip, Stanley R. *Computer-Based Instruction Methods and Development*, pgs. 166-170. Englewood Cliff, NJ: Prentice-Hall, Inc., 1985.
- Anderson, J. R. *Language Memory and Thought*. Hillsdale, NJ: Erlbaum Associates, 1976.
- Ausabel, D. P., Novak, J. D., and Hanesion, H. *Educational Psychology, A Cognitive View*. New York: Holt, Rinehart and Winston, 1968.
- Bobrow, D. G. Natural Language Input for a Computer-Solving System. In M. Minski, Ed., *Semantic Information Processing*. Cambridge, MA: MIT Press, 1968.
- Bruner, J. S., Goodenow, J. J., and Austin, G. A. *A Study of Thinking*. New York: Wiley, 1956.
- Gilb, Tom. *Principles of Software Engineering Management*, p. 259. Reading, MA: Addison-Wesley, 1988.
- Keller, J. M. Motivational design of instruction. In C.M. Reigeluth (Ed.), *Instructional Design Theories and Models: An Overview of their Current Status* (pp. 383-434). Hillsdale, NJ: Lawrence Erlbaum.
- Merrill, M. Component Display Theory. In C. C. Reigeluth, Ed., *Instructional Design Theories and Models: An Overview of their Current Status*. Hillsdale, NJ: Erlbaum Associates, 1983.
- Norman, D. A., Rumelhart, D. E., and LNR Research Group. *Explorations in Cognition*. San Francisco: Freeman, 1975.
- Puterbaugh, G., Rosenberg, M., and Sofman, R. Performance Support Tools: A Step Beyond Training. *Performance & Instruction*, November/December 1989.
- Reigeluth, C. M. Instructional Design: What Is It and Why Is It? In C. M. Reigeluth, Ed., *Instructional Design Theories and Models: An Overview of Their Current Status*. Hillsdale, NJ: Erlbaum Associates, 1983.
- Shriver, E. L., Fink, C. D., and Hart, F. *Maintainer Utilization Study (MUST)*. DOD Contract MDA903-83-L-0126. Final Report. May 1984.
- Shriver, E. L. and Trexler, R. C. *Situational Interactive Micro/Graphic Simulator System for Improving Maintenance Performance*. Final Report, AFHRL-TP-84-9. September 1984.